

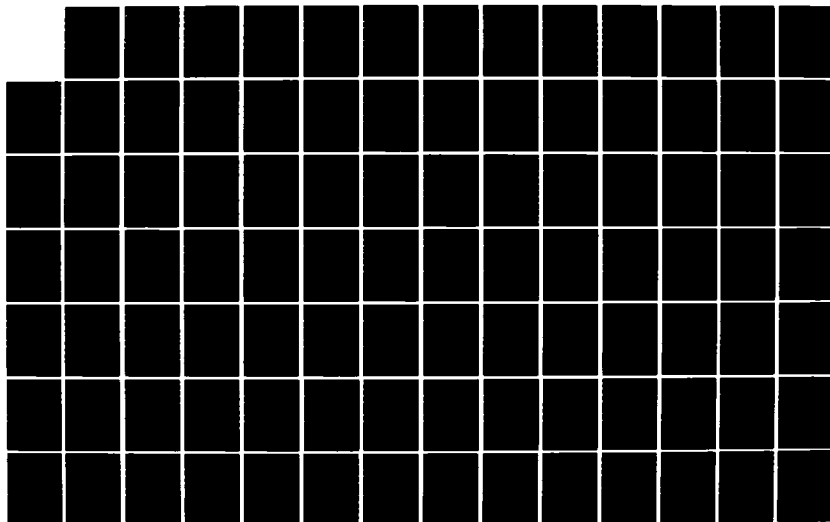
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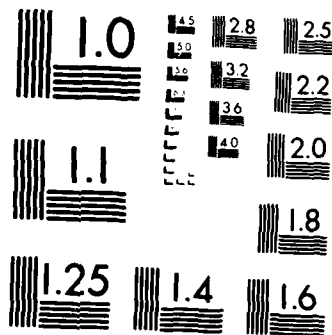
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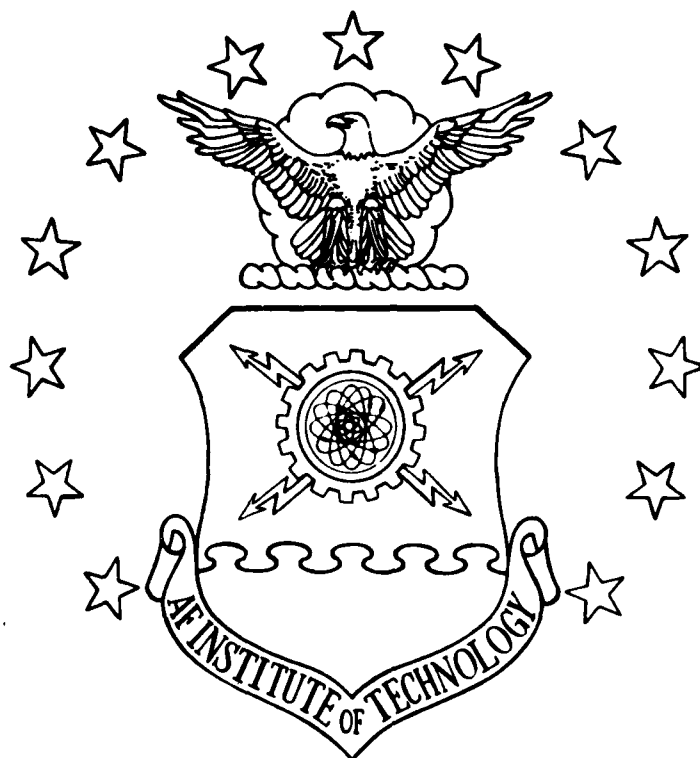




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ON THE DEFENSE DATA NETWORK

THESIS

Kevin R. Kavanaugh, B.S.
Captain, USAF

AFIT/GE/ENG/84D-40

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ON THE DEFENSE DATA NETWORK

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Electrical Engineering

Kevin R. Kavanaugh, B.S.
Captain, USAF

December 1984

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Preface

The purpose of this ~~study~~^{study} was to determine the efficiency of the application of the electronic mail system (INFOMAIL) on the Defense Data Network (DDN) and then conceptualize alternatives which would improve this efficiency. This is the first examination of the overall efficiency of this mail system on the DDN although previous efforts had addressed limitations in components of the system.

The scope of this effort concentrated on the interfacing between the various elements of the system from the terminal up through the DDN to the electronic mail host. This efficiency analysis did not evaluate the DoD standard interface protocols. Although this report specifically analyzed the electronic mail function on the DDN, it will provide information on any terminal communications application on the DDN.

I would like to thank my adviser Maj W. Seward of the Air Force Institute of Technology at Wright-Patterson AFB OH, for providing me with the essential guidance and encouragement in my efforts. Also deserving my appreciation for their contribution are Mr C. Morgan of the Defense Communications Engineering Center (DCEC), in Reston, Va, for providing the topic and sponsoring me, along with LtCdr R. Connell also from DCEC and Dr D. Hunt from Bolt Beranek and Newman Communications Corp., in Cambridge Ma, for providing me with timely support. And finally, I would especially like to thank my fiancée Sherry for being able to encourage and inspire me through our long distance telephone calls.

Kevin R. Kavanaugh

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Abstract

The highly centralized topology of the INFOMAIL electronic mail system, requires the transmission of inefficient packets, characteristic of a mail session, to traverse a considerable portion of the Defense Data Network (DDN). Alternative mail system topologies reduce this deficiency by distributing mail functions into network areas closer to the users.

The common user I/O device for the electronic mail interaction, the terminal, is inefficient in its use of network transmission bandwidth. Modification of the current terminal/DDN interface would improve this inefficiency particularly when more capable terminals, which could capitalize on this modification, are being deployed.

User interaction on the DDN from a network host computer is also inefficient in its use of the network's transmission capability. Alterations in the DDN/network host interface would reduce this inefficiency.

I. Introduction to the Efficiency Analysis of the Electronic Mail System (INFOMAIL) on the Defense Data Network

1.0. Background

The Department of Defense (DoD) utilizes a computer data transmission network known as the Defense Data Network (DDN) to effectively employ its large data processing resources. The DDN provides a communications link between major DoD computer systems (hosts) throughout the world, which permits the various processing resources, such as batch processors and computer databases, to be accessed by many users regardless of location (1:1). The DDN architecture, as depicted in Figure 1.0 below, connects the network resources and users through data transmission switches called Interface Message Processors (IMP), which are interconnected through wideband communications media. A user accesses a network host by establishing a connection through his supporting IMP to the IMP that provides network connectivity to his destination system. The data transmission technique for the DDN is packet switching, which is the quantization of user information, by the IMP, between network users into discrete packets and routing these units through the network. The IMPs temporarily store a received packet and then retransmit it on the communications line that provides the most expeditious path to the IMP supporting the destination user. At this point the data is reassembled into the source user message and then forwarded to the destination user. The destination user then transmits a message back to the source user to confirm receipt of the message and willingness to accept another. With this versatile communications system and the proliferation of data processing

equipment, the uses for this system are extensive. The following paragraph summarizes some of these requirements.

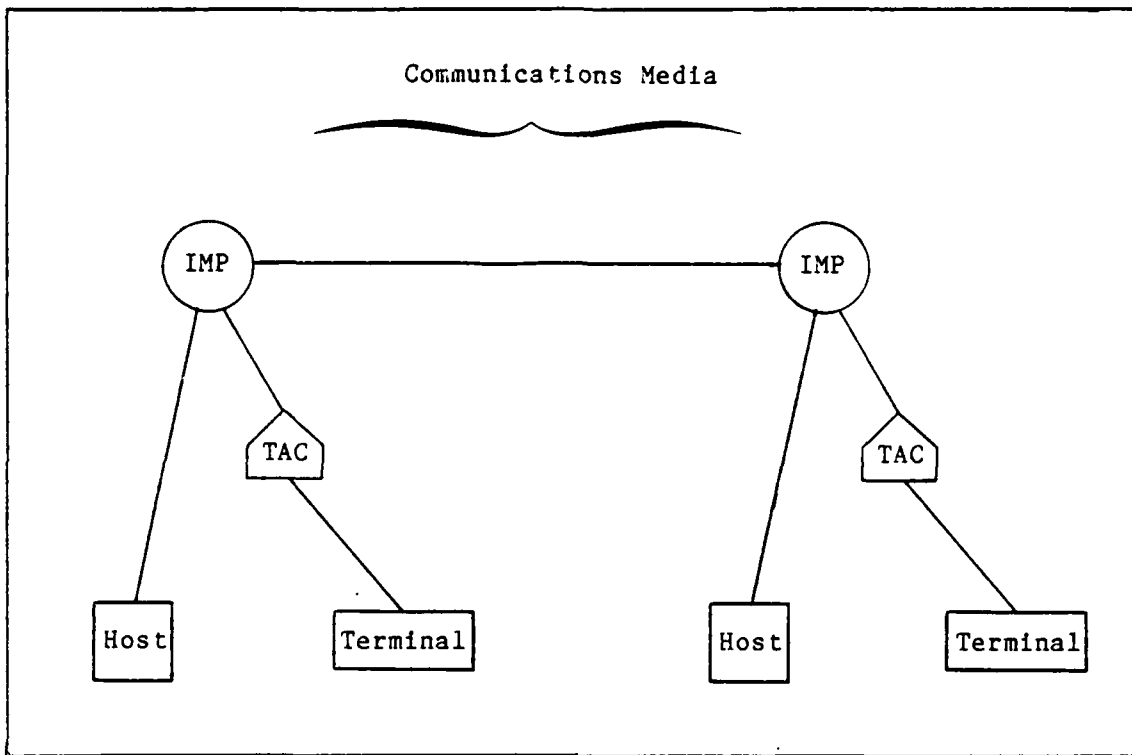


Figure 1.0. DDN Architecture

1.1. DDN Requirements

The DDN provides data transmission networking for several worldwide missions from connecting the large data processing facilities of the DoD research and development community to supporting DoD command and control communications. Figure 1.1 depicts the current DDN connectivity. Because of the defense oriented mission of the DDN, it must be able to provide reliable communications even through times of national crisis when normal communications might be disrupted by sabotage or direct attack. Communication survivability is provided through the multiple

routing of communications paths between IMPs, thus ensuring connectivity (1:8). As a communications path is broken, an alternate path is selected by the IMP. Alternate IMPs also provide switching redundancy to the DDN. The future requirements, for the DDN, are increasing with new users requesting connectivity. In addition, "The Department of Defense (DoD) has directed that all DoD data processing systems and communications networks that require a data communications service will use the Defense Data Network (DDN)" (2:42). This increase in the network connectivity will generate a significant amount of additional network traffic.

1.2. Electronic Mail

One application of the DDN is the ability to provide electronic mail service. A DDN user can compose an electronic message using the composition and editing capability of his mail supporting computer, much like a word processor. This supporting host can be accessed locally or through the network. The electronic mail is then released to traverse the network, if required, and is posted in the recipient's mailbox. Finally the recipient accesses his mailbox host and reads the electronic mail. This form of communications is becoming quite popular in the civilian and military communities as an alternative communications media to the telephone. Several networks have been established commercially. Last year there were over 440000 electronic mail customers sending 50 million messages (3:64). It is also competitive with the postal service because electronic mail can be transmitted electronically much faster than shipping a letter through the mail. The popularity of electronic mail on the DDN has its impacts as discussed in the following paragraph.

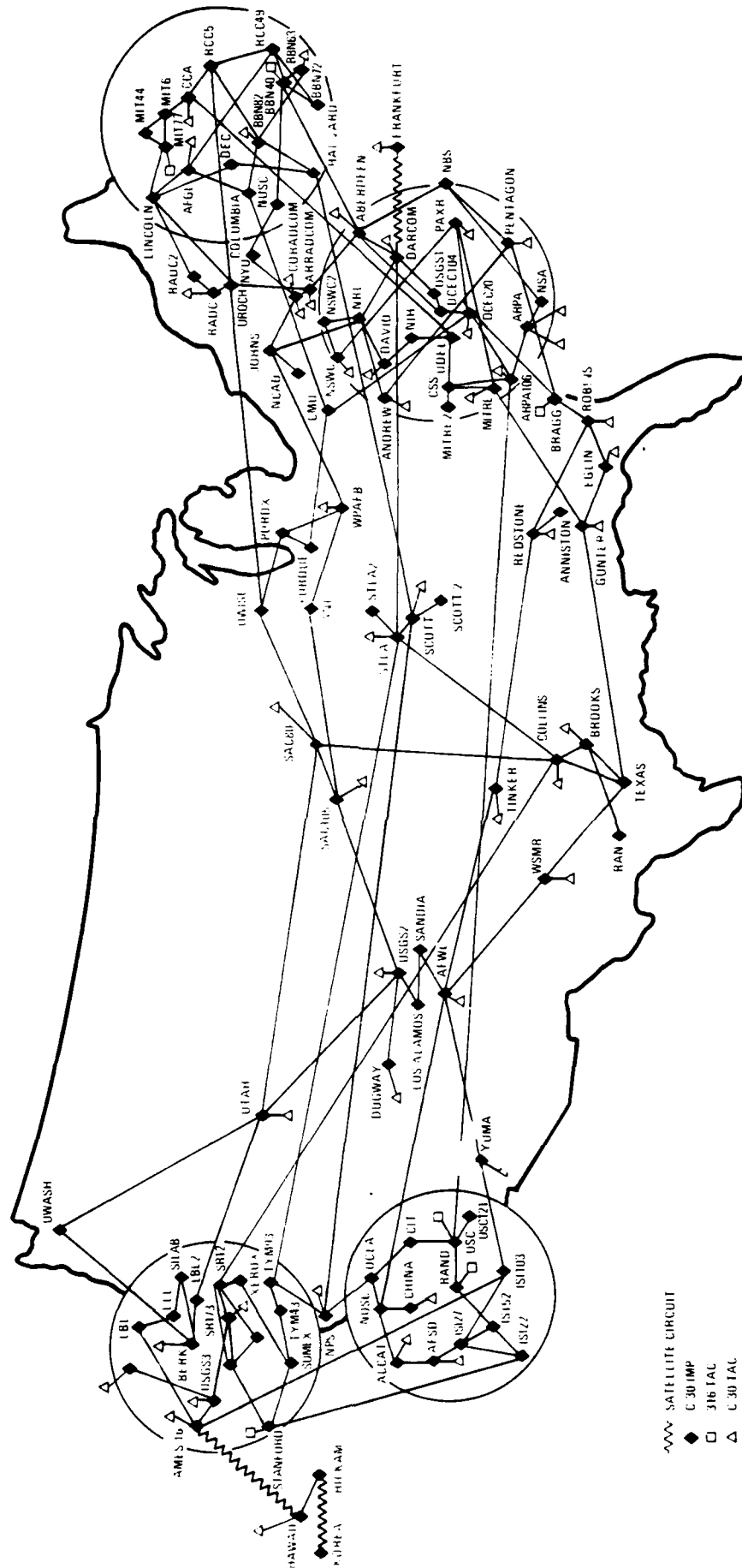


Figure 1.1. DDN Connectivity July 1984

1.3. Electronic Mail Problem

In addition to the known future requirements, there is a strong likelihood of unknown future requirements. If the expansion of the network, since its first operational cutover, is any indicator of the magnitude of future requirements, the DDN will be providing service to a significant number of additional users in the future. Historically, the number of network hosts has increased by 10% every year for the last four years and the network traffic has increased by 30% each year. As the advantages of interconnecting hosts into a network becomes more apparent to users and because more data processor equipment is being purchased, the number of network hosts is projected to increase by 20% a year (2:19). This, in turn, creates an increase in the number of packets being transmitted through the network. In addition, electronic mail is one of the applications of the network that is on the increase. Currently several mail systems are operating on the network. INFOMAIL, a commercial electronic mail system from Bolt, Beranek, and Newman Communications Corp, supports the Defense Communications Agency (DCA). It provides the mail functions, as previously described in paragraph 1.2. There are system inefficiencies in the current operation of the INFOMAIL system on the DDN, which do not provide the most transmission effective communications connectivity. The analysis of the INFOMAIL/DDN inefficiencies was the focus of this study.

1.4. Scope

This study analyzes these specific areas of the INFOMAIL mail system and its DDN components that provide connectivity to the user:

1. System topology and architecture in the DDN.

2. System component interfacing in the DDN.

The analysis addresses the following objectives:

1. Identify and characterize the most offending inefficiencies in the INFOMAIL system.
2. Develop concepts which can alleviate the above inefficiencies.
3. Prioritize inefficiencies identified, by their magnitude of inefficiency and the resources needed to rectify them.

1.5. Study Constraints

There are certain aspects of the INFOMAIL system, including its DDN connectivity, which are not addressed in this study because of the length of the software modification review cycle, contract limitations, or the item is a DoD or international standard that do not lend themselves to timely modifications. These constraints apply to the following:

1. All communications protocols.
2. DDN software modifications.
3. DDN backbone architecture.
4. INFOMAIL software modifications.

1.6 Study Approach

The most prevalent area of inefficiency in any large system consisting of heterogenous elements is usually in the interfacing of the various components. This study focuses on this area. The analysis of the INFOMAIL system was undertaken at the system and component levels. The topology of the INFOMAIL mail system on the DDN is compared to three alternative mail system topologies against various criteria. Each

topology is evaluated as to its affect on the DDN by applying a mail session model, which represents the typical user/mail host interaction. Also this comparison extends into a relative cost comparison of the acquisition and support requirements for each mail system. The third criteria, which completes the analysis, compares the different topologies relative operational effectiveness in providing system availability and reliability. The user I/O interface efficiency is also evaluated to determine the most effective technique to interface the user to the mail system. This entails an examination of network access techniques and their impact on the transmission efficiency of the network. In addition, a comparison of three representative terminals is conducted according to the criteria and techniques described for the topology evaluation. The results indicate the network resources generated by each configuration and also their relative standing in required financial and operational resoures.

1.7 Summary of Current Knowledge

Each packet contains a certain amount of overhead information which provides source/destination data, error checking capability, and network component information. This overhead information, although necessary, is wasted, in the sense that it is not user generated data. The length of a packet, in bits, varies depending on its application and network access technique, where one character or a group of characters can be carried. In one case, many small packets are required to provide the same data as a lesser number of large packets, which are therefore more transmission efficient than smaller packets in the utilization of the DDN communications. This transmission inefficiency, could cause network

congestion and increase network connectivity delays. Conversely, multiple large packets, although transmission efficient, have greater delay through the network than the smaller packets. An optimum network would be transmission efficient with minimum delays.

1.8 Summary

In brief, the INFOMAIL/DDN system is inefficient in its utilization of resources. This study analyzes both the mail system and the DDN components that provide connectivity to the mail system. The analysis determines the efficiency of the current system along with several alternatives. This results in recommended modifications to the present system. The following chapter provides additional background information to understand the basic components and concepts of the DDN and electronic mail.

II. ARPANET/DDN Background

2.0. Introduction

The concept of electronic mail is best understood with background information in computer communications. The particular computer communications network, which this study will cover, DDN, has its early development in the first packet switched network, the Advanced Research Projects Agency (ARPA) network (ARPANET). The basic requirement for a computer communications network was established when computers that were physically distributed in various locations needed to communicate. The development of the data communication network concepts and DDN components are to be addressed in this chapter with the specific details of one application of the network, electronic mail, provided in the following chapter. The first concept to discuss is the evolution of the network as described in the next section.

2.0.1. Distributed System

One of the most ambitious steps in the evolution of computer architecture was the design of the distributed local network. This concept allowed physically separate computers to share certain resources, such as printers and storage devices. As these resources were expensive and underutilized, this sharing by multiple systems helped justify the resource investment costs. The communication between the components of the distributed system take place over a transmission media such as coaxial cable depending on the computer-resource transmission rate. Resource control and interfacing is incorporated into a set of rules known as protocols, which establish techniques for

accessing and requesting the shared resources. The current utility of these local area networks is recognized in both military and civilian applications. The next logical extension of the distributed asset architecture would be the expansion of the network to include geographically separated computers and resources.

2.0.2. ARPANET Concept

In the mid 1960s the DoD was acutely aware of the need for specialized computer resources, particularly in the research and development area. High computational speed systems were required to run some of the most complex software, such as meteorological, aerodynamic, and nuclear weapons simulations. Because of the magnitude of these software programs and the wide geographical separation of the research facilities, specialized computers might be required at each location. In addition to the expense of acquiring and maintaining these systems at several locations, there was the inefficiency of underutilizing these assets when their specialized software was not in operation. To more cost effectively employ these resources, the concept of the distributed asset architecture was incorporated to interconnect these systems. The most ambitious and most successful application of this architecture was undertaken by the ARPA, now referred to as the Defense Advanced Research Projects Agency (DARPA). ARPA's original goals for the distributed network were to:

1. Develop and test computer communications techniques.
2. Obtain benefits of resource sharing for the ARPA community (5:41).

The original network started with four nodes in 1967. The growth of the system in numbers of users and capabilities provided to the users is phenomenal. In addition to the original capability of geographically separated computer to computer intercommunications, which allows a user at one computer the ability to access and interactively utilize the computer resources at a distant system, the ARPANET extended its interface capability to provide users access to the network with merely a terminal. Thus the significant capabilities of the network resources were made available to terminal users without the added expense of an interfacing supporting host. The ARPANET concept expanded out of the research and development community and into general purpose data communications. The following section addresses the development of the ARPANET based DDN along with its architecture.

2.1. Defense Data Network

The success of intercomputer communications networks, in the DoD, based upon the ARPANET has generated similar systems which provide connectivity to specialized missions. One example of a parallel network is the World Wide Military Command and Control System (WWMCCS) Information Network (WIN) which has been operational since 1975 utilizing ARPANET technology (2:3). Because of the proliferation of these DoD networks, in April 1982 the Deputy Secretary of Defense directed a reorganization of these networks into a combined DoD common user data communications network called the Defense Data Network. The current DDN, depicted in Figure 1.1, is based on an improved ARPANET technology which will provide multilevel security between network users and increased connectivity (4:1). Also, because of its increased

defense utility the Joint Chiefs of Staff determined that the DDN was to be designed to be survivable against threats commensurate with the users it supports (1:8). The use of highly reliable network components, in addition to adaptable connectivity, help to satisfy this objective. As seen in this Figure 1.1, the network has greatly expanded beyond the original ARPANET of four nodes. This network supports 400 hosts and 2000 terminals (2:42).

2.2. DDN Architecture

The significant tasks of connecting such a vast number of users with various types of equipment requires an unusual communications system. Unlike the telephone system there are no direct connections; all communications paths are shared for maximum efficiency. The following section describes the theory behind the data communications technique, packet switching, which makes the system possible. It also describes the significant components, along with their function, of the DDN.

2.2.1. Packet Switching Theory

The interfacing of the various computer systems to fulfill the ARPANET goal, required the development of a communications system that would be almost transparent to the members of the network. Requiring all hosts to adhere to a single specific set of parameters, such as transmission speed would compromise their capabilities and reduce the advantage of the networks, in terms of shared resources. The network itself had to accept the significant share of the burden in the interfacing of the various hosts. The network communications philosophy

utilized the technique of segmenting units of information, messages between computers, into discrete packets, which contained the source and destination address information in addition to the original data. This function is diagrammed in Figure 2.0.

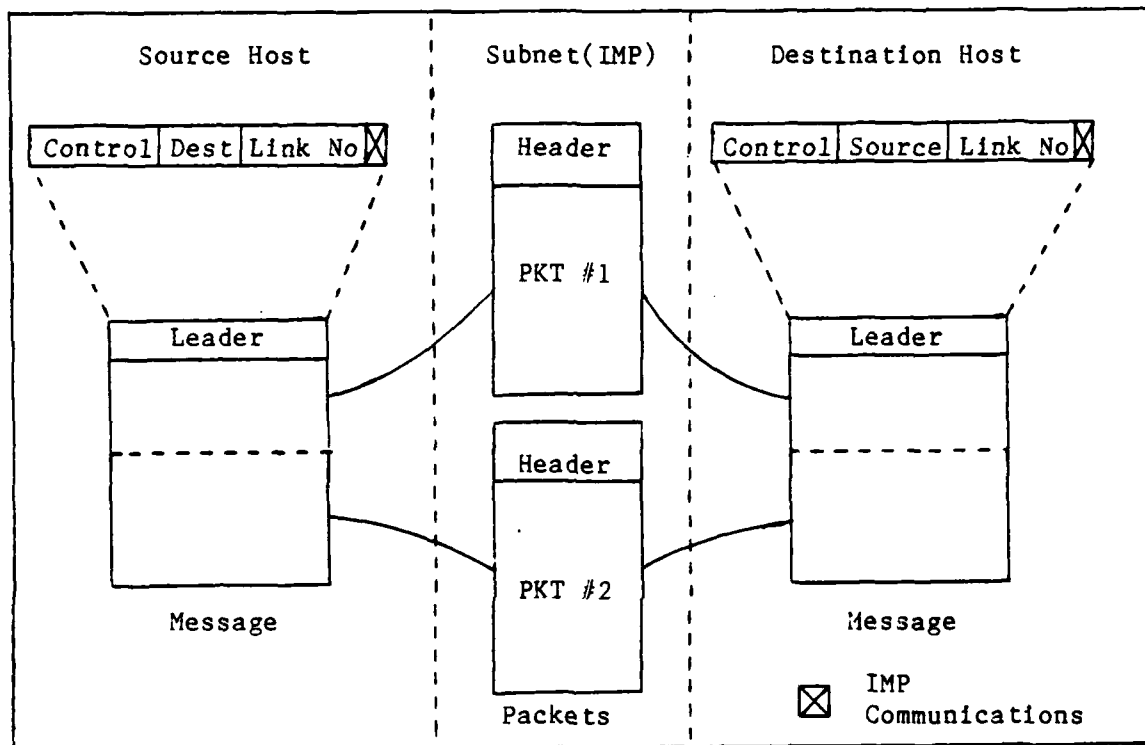


Figure 2.0. Message/Package/Message Transition

between two Network Hosts (6:378).

Communications between network users appears to be continuous, but in reality source data is segmented into packets, by a network node. It is then sent, via different routes and network nodes to the network node supporting the destination user, where the packets are reconverted into the source data. The length of the packet can be as great as 1008 bits with up to 8 packets per host message. The packets are utilized in a network implementation strategy known as store and forward, which has

intermediate network nodes from the source to the destination hosts store the received packetized information and then forward it when the communications line is available . This technique provides the maximum utility of the many communications lines between network hosts by forcing all hosts to time share them (7:339). The method used to determine which particular line should be chosen to route the packet is provided below.

2.2.2. Network Packet Routing Technique

The ARPANET pioneered the locally-determined adaptive routing technique. This method identifies the node to forward a packet through based on a routing table. This table, in turn, is continually updated through the shortest time path determined through the actual measurement of traffic delays. The distributed switching node architecture along with a requirement for dual communications connectivity provides multiple alternative routes to reduce delays and increase system reliability. It also eliminates system wide critical points, such as a central control facility. The loss of several nodes throughout the network will reduce system connectivity by isolating some network hosts and will also increase the utilization of the surviving network but communications will still be available (7:339). The components and a description of their functions that provide this survivable connectivity are discussed in the following paragraphs.

2.2.3. DDN Components

The elements of the DDN architecture that utilize the above theory are unique in their design of their hardware and software to incorporate

high reliability and unmanned operation. Hardware and software checks are continuously being accomplished to ensure reliable connectivity. The elements of the DDN that utilize the above theory are depicted in Figure 2.1 and discussed in the next section.

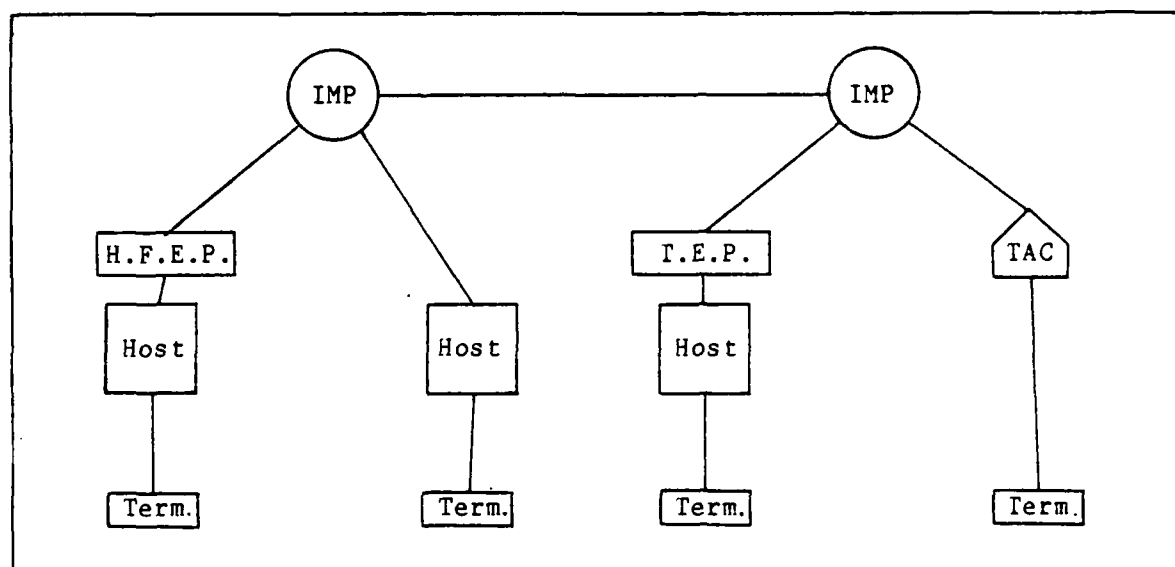


Figure 2.1. Representative DDN Network Components
and their Connectivity

2.2.3.1. Interface Message Processor

This is the most powerful component of the network. It is a computer controlled packet switching node that specifically:

1. Routes packets through the network by receiving them on the input line, reading their destination, and then depending on their destination, forwarding them to their node serving the destination host or its own host.
2. Packetizes messages from its local network user and transmits them on the network.
3. Reassembles packets with its network user as the destination into

messages and forwards them to that user.

4. Retransmits packets to a destination node if the previous packet was not acknowledged.
5. Checks packets for transmission errors.
6. Collects performance statistics utilized for packet routing, system analysis, and control.

The IMP function is performed by an unattended C/30 packet switching processor, designed for high reliability through redundancy, self monitoring capability, graceful performance degradation instead of catastrophic failure, and automatic program reload capability (8:65). Functionally the IMP provides an almost universal interface between the multitude of host computers and the network. Some of its specific capabilities are the following:

1. Traffic throughput of 300 packets/second tandem processing (ie. 300 in, 300 switched, and 300 out simultaneously).
2. Processing delay of under 1 millisecond unloaded, with 1-2 milliseconds moderately loaded, and 2-3 milliseconds heavily loaded.
3. Routing bandwidth and CPU overhead of less than 2%, and a reaction to topological or significant delay changes in less than 100 milliseconds (1:34).

2.2.3.2. Terminal Access Controller (TAC)

To provide network access to the terminal without a local network host interfacing to an IMP, the Terminal Interface Processor (TIP) was developed for the ARPANET. This component was a variation of the IMP that provided additional hardware and software to support communications

with terminals. The TTP was replaced by the Terminal Access Controller (TAC), which although similar in function to TTP system, segmented terminal control and the IMP functions into separate components. The TAC is a transmission speed adaptable component that can provide connectivity to 63 terminals, via an IMP, to the network. The IMP views the TAC as a host to the terminal. The TAC is designed for unattended operation and high reliability (9:2).

2.2.3.3. Network Access Component (NAC)

The current interfacing between the user's host and the network requires a common set of protocols, which ensure communications compatibility among the network users. The network protocol implementation can take place in two ways depending on the extent of the modifications of the host the user can afford and also the network capabilities that the host requires. The internal technique has the user's host, either in application software or in the operating system, provide the required protocols. This method often requires extensive programming and it is only as time responsive as the host. The external technique provides a hardware interface device, which performs the protocol interconnection between the network and user's host (10:13-16). There are two techniques of providing the external network access to a host which are described in the following paragraphs.

2.2.3.4. Terminal Emulation Processor (TEP)

This method attaches a protocol device to existing terminal ports on the host. The effect is that terminals on the DDN can access this host through the TEP; however, local terminals connected to the host

cannot access the network through this host. The segregation of host and network responsibilities, in terms of communication protocols, makes this network access simple, requiring no host software modifications but only provides limited network communications because it utilizes the host's terminal ports (10:18).

2.2.3.5. Host Front End Processor (HFEP)

The preferred technique used to externally interface a host with the DDN is through a protocol interfacing device, known as the Host Front End Processor (HFEP). Unlike the TEP, this access component is connected to an I/O port on the host system, and requires a common Host Front End Processor protocol with the host. This requires some host software modifications and is therefore as responsive as the host. It provides a higher data transmission speed than the TEP and is still simpler to implement than the internal network access techniques (10:16).

2.2.3.6. IMP to IMP Backbone Communications Media

The switching nodes are connected through leased wideband communications media at a 50-56 kbps rate. There are also three 7.2 kbps links currently connected through satellite channels. Dual communications redundancy out of each IMP provides reliable connectivity. Protocol error checking by the IMP provides a worst case 1×10^{-14} bit error rate performance with improvements up to 2.9×10^{-19} bit error rate, depending on the communications protocol (1:7).

2.2.3.7. Host to IMP Communications Media

Connectivity from the host to the network, through an IMP, has

several possibilities. Each IMP can support hosts operating at transmission speeds from 2.4 to 230 kbps. The host operating system contains an end to end protocol that provides resource allocation, communication initiation, and transmission error checking between hosts (1:34).

2.2.3.8. Terminal to IMP Communications Media

Network access from the terminal to its respective IMP is accomplished through the TAC at 75, 110, 134.5, 150, 300, 600, 1200, 1800, 2400, 4800, and 9600 bps asynchronously. TAC connectivity to the IMP is at 100 kbps synchronously. Several connectivity options support the terminals such as:

1. Permanent line access.
2. Dial-up line access.
3. Multiplexed terminal support.

The TAC provides data flow and an end to end communications protocol. The parity bit provides the only error checking capability from the terminal to the IAC (9:2).

2.2.3.9. Network Information Center (NIC)

This manned component of the network monitors the overall performance of the system and also provides system analysis and maintenance functions, in addition to answering user inquiries. System software updates are also performed by the center (1:59).

2.3. Electronic Mail Concept

Although the original goal of the ARPANET was intercomputer communications, there was a side benefit in the form of user to user

communications capability. In other words instead of utilizing a host on the network to either execute a program or access its database, a user could generate a file containing a text message and then transfer it through the network to another host. This text message transfer capability evolved into electronic mail, which is a block of text complete with destination information from one user to another. A certain host, that is common to mail users, provides a storage file or mailbox for each user. Generation of the electronic mail, by the users, can be accomplished at this or another accessed host and then transferred or mailed to the recipient's mailbox. Electronic mail is available on most commercial and military networks. It supplements the telephone as a cost effective component of an office with advantages of no busy signal or an individual not being available; both problems of real time communications, which is exasperated by differences in time zones. Electronic mail is also becoming another function of the electronic office work station, which provides word processing, database access, files management, interoffice memo processing, and now electronic mail. The following paragraph briefly summarizes the capabilities of the electronic mail system that was analyzed in this study.

2.4. INFOMAIL Capabilities

The Defense Communications Agency (DCA) utilizes the commercial system, INFOMAIL, for its electronic mail support on the DDN. The INFOMAIL system provides more capabilities than just electronic mail, by supporting the user with an electronic file system. In addition to the composition and editing capabilities for generating the mail, it can

also create entire documents or "import" existing electronic documents into the mail host for filing or transmission to another mailbox. File manipulative capabilities extend from file scans, which provide a listing of the source and subject of all mail/documents in the file, to specific file searches (11:2-1). In addition to the above capabilities the system's user friendliness, to include word parsing, spelling correction, and display tailoring, enhances its usefulness.

2.5. Summary of ARPANET/DDN Background

This chapter examined the basic data communications network concepts which led to the development of the DDN. In addition, the function of the DDN components and the network application of electronic mail, in particular INFOMAIL, were also addressed. This information has provided the necessary introduction to the following chapter which is an in depth description of the INFOMAIL operational concept.

III. Electronic Mail Theory of Operation

3.0. Introduction

The INFOMAIL/DDN mail system operations concept is developed in this chapter because a thorough knowledge of the theory and architecture provides a better understanding of the analysis in the subsequent chapter. An example of a typical mail session is also included in this section to help establish this understanding.

3.1. Electronic Mail Theory

One of the most important requirements of the network is the need to transfer files among the various network users. A file is defined as a block of data or information which can be addressed and controlled as one integral unit. It may be a machine language program or a text of characters. The user's supporting host operating system generally provides the basic file management capabilities of composing, editing, reading, storing, and discarding files. In the case of the network, file transfer is essential for inputting programs on shared computational resources. Electronic mail is merely file management with a network transfer capability (12:300). The user generates, through the file composition capability of either a local or network host, a file containing the text of his mail. It also includes the name and address of the receiving user. The file is then transferred, via the network, to the destination. If the receiving user has a mailing account on the same electronic host as the sending user, it is a simple internal file transfer within the local mail databases. If the receiving user has his

account on a separate network host the mail host transports the file through the network to the destination host. Basic file manipulation techniques of the destination host store the incoming file and notify the receiving user's account of its arrival. File access and reading is accomplished as if it were a file generated by the receiving user's host.

3.2. Electronic Mail Architecture

Since the electronic mail concept is merely a file manipulation and transfer capability, its architecture is not unique in comparison to other databases of the network. The major components of the INFOMAIL mail system architecture are depicted in Figure 3.0. and are addressed in this section, whereas the function of these components is discussed in the subsequent section.

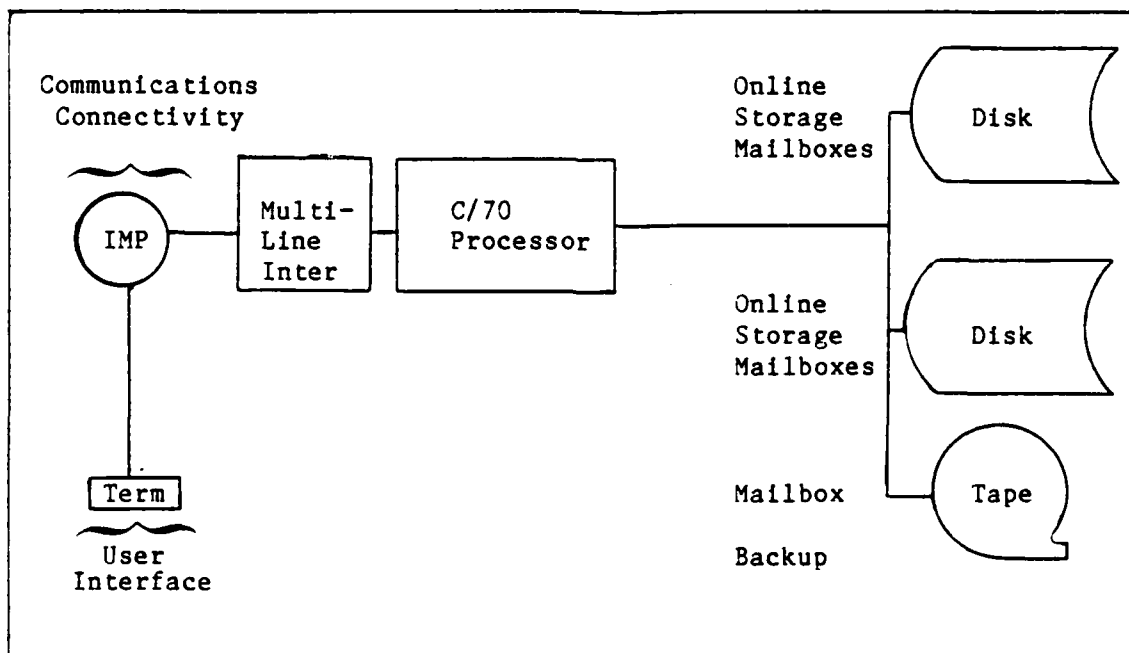


Figure 3.0. INFOMAIL Electronic Mail Host Architecture

3.2.1. Electronic Mail Host

This component of the system contains the mail application software for generating, processing, storing, and transmitting the electronic messages. It is either resident on a specialized mail host, which is used strictly for electronic mail, or as an addition to the operating system of a multifunction host. The host computer is characterized by an extensive communications interface with its users, through remote terminals or network nodes, and with a large secondary storage medium to contain the system database files, which hold the users' mailboxes. The amount of secondary storage is determined by the number of mail users and the size of their stored files. Another storage medium is sometimes used to provide backup file storage. If electronic mail is being sent to a different mail system on a separate network, a gateway mailer is required. Specifically, the gateway contains the capability to communicate between the various mailing networks. In addition to temporarily storing mail in transition while the network address of the destination host is being converted, the gateway mailer reformats the mail packets to meet the requirements of the destination's network (13:3).

3.2.2. User Interface

The man/machine interface for the system is provided through some interactive terminal. It allows the user the control of the electronic mail software to generate, process, and transmit his mail. The range of possible terminal equipment extends from the teletype terminals, which provide simple character to bit translation and rely extensively on the

mail generation capabilities of the electronic mail host, to local host supported terminals, which provide local mail composition, editing, and rely only on the mail host for mail transfer and storage. Their capabilities along with their logical interface with the mail system determines the amount of support required from the network and the electronic mail host.

3.2.3. Communications Connectivity

The goal of the electronic mail system is to transfer information between locations. The packet switched network provides this connectivity between the terminal and electronic mailhost either both connected to the same network node, or separated by several nodes. The electronic mail and terminal support hosts interface directly to IMPs, while terminals interface through TACs into an IMP. Since the majority of the network now supports interactive terminal access, the TAC has become an important element of the network. Dial-up service to the TAC is also expanding in the network due to the limited number of full time connection requirements, such as found in most of the electronic mail community.

3.3. Electronic Mail Functional Elements

The analysis of electronic mail can only be accomplished with an understanding of the functional elements of the system which represent the logical flow of a piece of mail between the user and the mail host. Integrating the above architecture with the specific functions described in the following paragraphs results in the electronic mail functional model depicted in Figure 3.1.

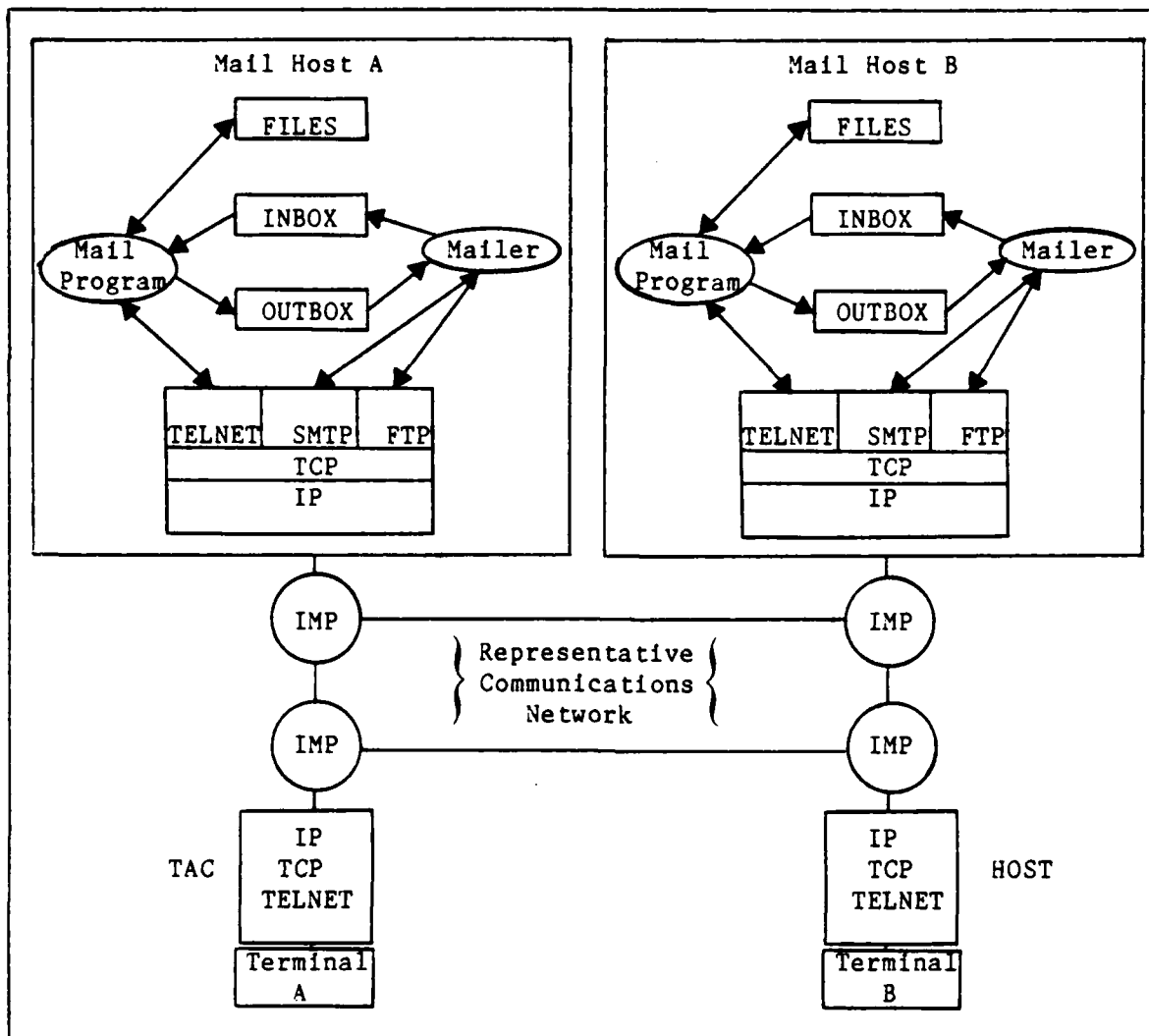


Figure 3.1. Electronic Mail Functional Model (14:96)

3.3.1. Mail Holding Areas

The file directories (INBOX, FILES, and OUTBOX) for a user's mail are indicated in Figure 3.1. These are the logical mail holding areas which, using office terminology, indicate the possible locations of electronic mail. They include both mail messages and larger files that would be stored in an office. INBOX refers to mail pending review; OUTBOX refers to mail awaiting transmission to another mail user; and FILES refers to archived mail (11:1-1).

3.3.2. Mail Program

This is the portion of the actual mail system that functionally interfaces with the user. It provides the electronic mail documentation generation capability, such as composing, editing, discarding, in addition to the transfer ability between the mail holding areas ie. INBOX, OUTBOX, FILES (14:94).

3.3.3. Mailer Program

The actual transfer of electronic documents between users is accomplished by this component of the mail system. It is not interfaced with the user directly but transmits documents in the OUTBOX to their addresses either internally, for a user on the same system, or through the network for a different mail host without the user having to access the remote system. Incoming mail to an electronic mail host is also distributed into the appropriate recipient's INBOX by this software (14:55).

3.3.4. Interface Communications

The standardized interprocess communications between the elements of a network are controlled by protocols. These rules dictate the techniques necessary to ensure complete interface compatibility for communications, between the various elements. The specific protocols to interface the electronic mail system with the DDN are required by the DoD and are indicated in Figure 3.1. The various layers, as seen in Figure 3.1, segment the protocol responsibilities. Each protocol layer accepts information from the layers above and passes its results to the layer below. Also each layer performs its function by communicating to

its counterpart protocol at the other end of the connectivity. For instance the TELNET protocol, in the mail host in Figure 3.1., communicates with the TELNET in the TAC. The following section addresses the function of the various protocols required for mail operations.

3.3.4.1. Simple Mail Transfer Protocol (SMTP)

This application protocol provides the mechanisms for the transmission of mail directly from the sender mail host to the receiver mail host. Specifically, the sender-SMTP establishes a two way transmission channel to a receiver-SMTP. Through this channel the sender and receiver SMTPs send commands for locating the receiver's mailbox, transferring the mail data, and confirming the transactions. INFOMAIL utilizes SMTP to transmit electronic mail to other non-INFOMAIL mail systems (15:5).

3.3.4.2. Telecommunications Network Protocol (TELNET)

The technique for interfacing a remote user either at a terminal or his own host through the network to an electronic mail host is accomplished with the TELNET application protocol. In essence, the TELNET provides a user at a terminal with the control over a remote host as if he were a local user of that host. Some of the capabilities of the TELNET protocol that are available to the user are the following:

1. Initiate a pair of connections to a serving host.
2. Send characters to the serving host.
3. Receive characters from the serving host.
4. Send a host-host interrupt signal.

5. Terminate connections.

Its application extends beyond the strict electronic mail function and covers all terminal communications (8:38).

3.3.4.3. File Transfer Protocol (FTP)

This application protocol establishes the mechanism for transmitting files across the network. This function is essential in the transfer of programs and data base upgrades between network hosts. It specifically provides an FTP user the capabilities to:

1. List remote directory.
2. Send local file.
3. Retrieve remote file.
4. Rename remote file.
5. Delete remote file.

FTP relies on TELNET to establish the connection between the network hosts before it transfers the file. The INFOMAIL supported host utilizes FTP to transfer mail to another INFOMAIL supported host (10:8).

3.3.4.4. Transmission Control Protocol (TCP)

As indicated in Figure 3.1., the next protocol layer under the TELNET and SMTP protocols is the TCP. This host to host protocol provides reliable interprocess communications between the electronic mail host and the user terminal. It specifically enables the following:

1. Establishment and maintenance of interprocess communications.
2. Transfer a continuous stream of eight bit words in each direction by blocking them and transferring them to the next protocol layer.
3. Maintain reliable communications by providing eight bit word

sequencing and accounting.

4. Control the flow of data transferred between the sender and receiver systems.
5. Multiplexing of several processes within a single host to communicate, using TCP, simultaneously.
6. Generation of a level of priority and security between the various communications being undertaken by the TCP.

The TCP software is called by the upper level protocols to provide the above functions (16:5). It in turn, calls the Internet Protocol, which is addressed in the next paragraph, to perform the next step in the development of the communications connectivity.

3.3.4.5. Internet Protocol (IP)

The IP is designed for use in interconnected packet switched systems, where conversion from one packet size to another is required. Even though a message does not leave a network, the IP is still required by DoD directive. Functionally, the IP could be bypassed for communications within the same network. This host to host protocol is called by the TCP to fragment and reassemble a large block of data or datagram, if possible, to interconnect with another network where a more length constrained packet is required. The other major function of the IP is to map the internet addresses for packets to local net addresses. The higher level host-to-host protocols mapped the names to addresses for the IP and the lower level or local network protocols map the local net address to the actual route on the network (17:78). IP interfaces with the next lower level of protocols called the network access protocols, which are discussed in the following paragraph.

3.3.4.6. Network Access Protocols

These protocols define the communications interface between the network component and the network and address the actual electrical transmission of data. Specific protocols are dependent on type of host, distance from the IMP, and host interface protocols available. The remainder of the mail functional model which provides the communications connectivity and user I/O are discussed in the next section.

3.3.5. Communications Network

The packet switching network is locally accessed for the user terminal and electronic mail host through a network node, IMP. A terminal without a local host to interface to the IMP must be supported by a FAC. Connectivity can extend from utilizing the local network node to provide, either local access to the electronic mail host connected to the same node, or to multinode paths across the network to a mail host serviced by another node. Packet sizes can vary from one character per packet, when working interactively with the mail host, to large multipacket messages, when a document is being transmitted. Network access is controlled at the network nodes along with establishment of the connection and routing to the mail host interface node. Interprocess communications, complimentary to the electronic mail host, are accomplished at the user's host if network access is through a host to an IMP, otherwise the FAC provides this protocol support to the terminal.

3.3.6. User Terminal

The man machine interface between the user and the mail host is

the terminal. It provides access and control of the electronic mail functions and is the I/O data port for the system. Its capabilities can vary depending on equipment which determines what additional support can be provided, such as mail composition, editing, and file storage, to the system. An example of how this functional model actually works is provided in the following paragraphs.

3.4. Electronic Mail Operation

The following section describes the sequence of events, as depicted in Figure 3.2., required to utilize INFOMAIL. It demonstrates a typical mail session that is representative of how INFOMAIL is utilized. This representative mail session, along with its connectivity, is not to be considered the only configuration for the mail system but only as a thorough demonstration of the various mail system components. Other mail system configurations are discussed in a subsequent chapter.

3.4.1. Mail Host Access

A generic electronic mail session, where user A is generating and sending mail to user B, is depicted in Figure 3.2. below. The process is initiated by the user on terminal A getting access to his local TAC and subsequently to his electronic mail host through the packet switching network. The TELNET protocols are used during the access to ensure interface compatibility by establishing a common set of operating parameters between the TAC and the mail host. After the connectivity has been provided, the user begins his mail session which is discussed in the following paragraphs.

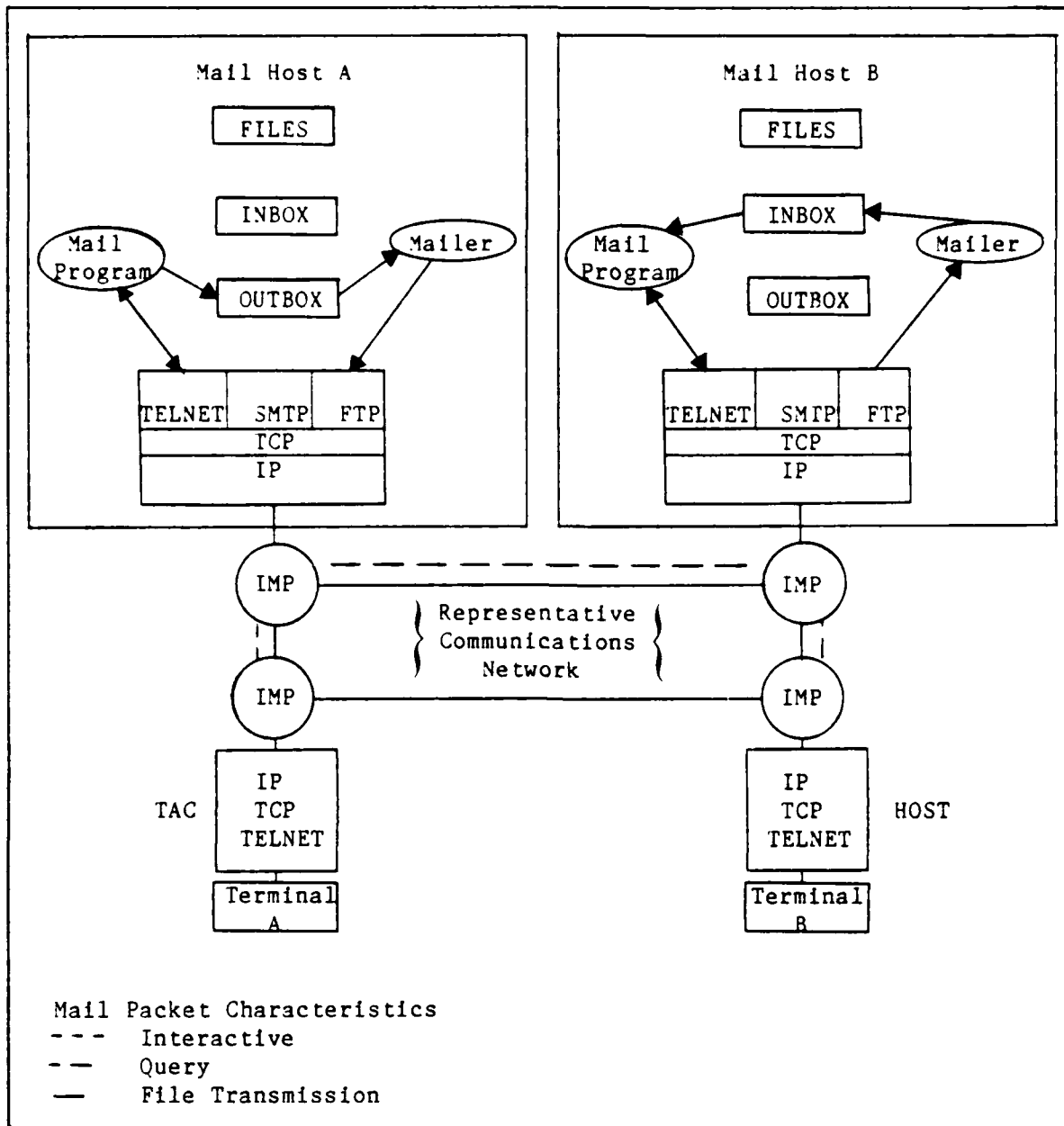


Figure 3.2. Representative Mail Operation (14:99)

3.4.2. Mail Generation and Editing

User A's terminal accesses the mail program for the mail program composition and editing. At the conclusion of the mail composition, the electronic document is put in the OUTBOX status until the user transmits the contents of the OUTBOX. The mailer then packages the document with

the mailbox address of user B, initiates interprocess communications, through TELNET, with user B's mail host, and then transmits the mail via the packet switched network, by use of FTP, to user B's electronic mail host. If user B had been on the same mail host as user A, then a simple access privilege would be sent to user B's mailbox instead of transferring a file. SMTP would be required if user A were to transmit the mail to a non-INFOMAIL mail system.

3.4.3. Posting Electronic Mail

The mailer routine for user B's mail host posts the incoming mail from user A into user B's mailbox. Note that user B does not have to be logged on to his mail host to have his mail posted. If user B's mailbox is on the same mail host, an indicator that this piece of mail belongs to him is sent to his INBOX; and in the case of multiple copies only one copy is retained for the entire mail data base. Indicators that mail is available for all addressees are placed in their INBOXes.

3.4.4 Mail Reading, Discarding, Filing, and Replying

User B has gained access from his terminal through his host and the packet switched network to his electronic mail host. The TELNET interface in this case is provided by user B's host operating system. Upon logging into his mail host, the mail program provides him a quick summary of the contents of his INBOX, which now has the electronic mail from user A. User B reads the mail and then he can either compose a reply, discard, or file the mail. The reply uses the same sequence of events as the mail generation.

3.5. Summary of the Electronic Mail Theory of Operation

The electronic mail system is merely a file manipulation and transfer system taking advantage of the wide connectivity of the packet switching network. The required hardware consists of user access devices connected, via the network, to hosts with a storage media. The following chapter utilizes the background provided by the first three chapters to specify the efficiency criteria of the electronic mail system evaluation.

IV. Efficiency Evaluation Criteria

4.0 Introduction

This chapter describes the criteria and an outline of its application technique that were used to evaluate the efficiency of the INFOMAIL and the DDN components that support it. The background and theory of electronic mail and the DDN has provided the necessary information to comprehend the specific details of this chapter. The subsequent chapters apply these techniques and criteria in the actual evaluation. The analysis of the INFOMAIL system attempted to answer the two following questions:

1. How efficient is the current INFOMAIL/DDN system in providing electronic mail support?
2. What alternatives are available to improve the efficiency of the INFOMAIL/DDN electronic mail system?

These questions structure the analysis into an evaluation of the current method of providing electronic mail support along with alternatives which should improve the efficiency of the current method. The final result are recommendations as to the preferred method to be implemented. These recommendations are prioritized in order of the magnitude of the inefficiency that they rectify and also according to the amount of resources required to implement them. The system evaluation of INFOMAIL examines the topology of the electronic mail host to user connectivity. This indicates the effects of distance and mail host architectures on the system efficiency. Using a representative user to mail host network connectivity, the INFOMAIL system along with

three alternative mail systems were compared in various efficiency categories to be described in the next section. The next logical progression in the evaluation was on the component level, where each element of INFOMAIL/DDN, from the user's I/O device up to the network IMP, was examined to determine the most efficient configuration to interface the user to the network. To understand the direction of the analysis, the term "efficiency" is qualified into the INFOMAIL/DDN system resources discussed below.

4.1. Efficiency Analysis Criteria Determination

The efficiency of a system can be quantified by examining the amount of output against the required resources to achieve that output. This same philosophy can be applied against the INFOMAIL application in the DDN. The required resources are the investment cost of the hardware and software, the network transmission bandwidth, and also the user's time and effort in utilizing the system. This combination of resources cover the most significant issues needed for a decision to implement and operate a new system or modify an existing one. The evaluation techniques that are used under these criteria are both deterministic, for demonstrating specific differences between alternatives, and also logical, for relative comparisons of the alternatives. Not all of these criteria can be applied to each part of the analysis. In each case the applicable criteria and their specific evaluation technique are described, in the subsequent chapters, prior to the analysis of that portion of the system. The evaluation was bound by the following assumptions:

1. The currently engineered DDN hardware and software cannot be

modified for this particular application. The system manager (DCA) will not allow the DDN to be modified to meet a specific application requirement.

2. The JCS system connectivity survivability criteria does not apply to this particular application although most users would benefit from its survivability.
3. There is no formalized documentation on DCA's specific requirements for INFOMAIL. The software is a commercial product leased by the government. Analysis of the system in meeting specific requirements are therefore to be based on the understanding developed through discussions with DCA personnel and provided in Chapters 2 and 3.

Under these guidelines the efficiency of the system was evaluated based on the following criteria which are described in detail below.

1. Financial Resources.
2. Network Resources.
3. User Interoperability.

4.1.1. Financial Resources

A thorough evaluation of a requirement and the alternatives to satisfy it, would ordinarily require a complete economic analysis. This requirement was determined, by the Defense Communications Engineering Center (DCEC), to be out of the scope of this study. However, DCEC also specified a requirement for a prioritization of recommendations based on the financial resources necessary to implement them. The solution to this dilemma was to provide at least a relative standing of the alternatives according to their required financial resources. The

strategy for determining the relative costs of one alternative against another is a complex one. It relies on the numbers of each alternative or its components along with its expected development, procurement, installation, operations and maintenance costs over a certain life cycle. This figure also includes the start-up costs of establishing training, constructing facilities to house the system, and procuring the initial spare parts. Because of the complexity of the optimization of these variables coupled with their unknown magnitude, the relative comparison between these variables was somewhat subjective. An example of this comparison and the difficulty that balancing the various financial resource components, is evident with the comparison of a new minimally manned system against a conquerable existing manned system. The tradeoff between the unknown costs of developing the minimally manned system must be weighed against the long term cost benefits of the reduced manning in comparison to the existing manned system. The above components of the financial resources can be grouped into two categories. The one time investment or non recurring costs cover the system development, procurement, installation, and start-up costs. The non recurring costs contain the yearly operations and maintenance costs. The uniqueness of each evaluation dictates that the specific prioritization of the financial resource components be provided just before that portion of the analysis is accomplished. The next step in the INFOMAIL/DDN efficiency analysis was the determination of each alternative's required network resources which is addressed in the following paragraphs.

4.1.2. Network Resources

Unlike the relative evaluation of the alternatives based on their required financial resources, the magnitude of their required network resources is more structured. The evaluation of a system or device according to its network resource requirements was accomplished in two ways. One method identified the theoretical network resource requirements based on an examination of the item's capabilities and limitations. The other technique computed the item's network resource requirements based on its performance against a user model. This was accomplished through the application of a representative mail session model into the system or device under evaluation. This model was initially developed by BBN during the design of electronic mail system which supports the DoD European logistics movement system. The Movement Information Network (MINET) mail session model was modified by BBN to enhance its applicability to electronic mail on the DDN. A further modification of the MINET model was performed for this study to more accurately represent DCA's correspondence style. The resulting network resources were then calculated for each mail operation. Also a comparison of mail system topologies, on a representative network, provided network distance, in numbers of IMPs traversed per mail function. Depending on the item under evaluation one or more of the above techniques were used in their comparison of the alternatives. The following paragraphs describe a breakdown of the network resource criteria into its components and address the various network dynamics resulting from the different numbers and sizes of packets and user requirements.

4.1.2.1. Packet Size Comparison

The number of bits that constitute a packet determines the utilization of the packet as part of the communications system. Each packet requires 520 bits of overhead information which provides the communications protocol, error checking, destination and host addresses, and inter-IMP communications in addition to the original host information. This overhead is wasted information in fulfilling the network's communications connectivity requirements for the user. The three traffic patterns between the user and the mail host and one mail host to another mail host are either interactive, query/response, or file transfer. The specific identification of each pattern to a particular mail function is done in a later section. Each pattern has a unique impact on network resources and also specific requirements. Interactive actions are short one at a time tasks and typically are repetitive processes such as typing in text. The packet characteristics from this action are many small packets. Their transmission efficiency is low. Query/response actions are a combination of short and long tasks as in a user's question about some information and the system's answer. This results in a few small packets for the query and several large packets for the response. The transmission efficiency for this pattern is not very high. The last traffic pattern is file transfers between two network hosts. The packet characteristics are a few large packets or multiple packet messages with high transmission efficiency. The other major contributor to the numbers of small packets are the message and packet acknowledgements which are returned to the transmitting hosts and IMPs to confirm message or packet receipt. The

echo from the network host is also in this same category. The advantage of the small packet is that due to its small size, its network transit time is short, which is desirable in an interactive environment. This is due to the time required to finish transmitting the host message and subsequently the packet from the IMP, which results in the receiving IMP sending an acknowledgement all the sooner. This in turn allows the transmitting IMP to discard the copy of the packet and free up valuable buffer space for another message which reduces overall packet waiting time in the IMP. The smaller size packet also has a higher probability of finding available buffer space in the IMP reducing retransmission attempts to the IMPs. Finally, because of the packet or message's small size the probability that a random error, due to noise on the transmission line, will disrupt it, is lower than a larger packet. This results in fewer retransmissions for faulty packets. The optimum size of the packet is a function of the communications line transmission performance, with high quality lines leading to bandwidth efficient large packets, while poor quality lines make the small packet more viable (8:186). The evaluation of the alternatives, utilizing the mail session model determined the number and size of the packets generated. Small packets reflect a poor utilization of the network resources and should be minimized for a network efficient system. An optimum system utilizes the full 1003 bits of a single packet. The use of multiple packets and their advantages and disadvantages in comparison to the single packets is reviewed in the next paragraph.

4.1.2.2. Single vs Multiple Packet Message Comparison

The DDN handles large, non interactive transfers between network

hosts with multiple packet messages. This means that a large message, from the source host, entering the network is segmented into multiple packets by the source IMP, which then transmits the packets individually, possibly through different paths. The destination IMP reassembles the original message from the multiple packets, also discarding duplicate packets, and forwards it to the destination host. There is a distinct difference in network response time performance between the multiple and single packet messages. The packet buffer reservation system in the IMP allows single packets regardless of size to be transmitted to the next IMP in their connectivity towards the destination host as soon as the IMP's communication function is available. The multiple packet message must have reserved storage buffers at the destination IMP before it can transmit the multiple packet message because it must reassemble the multiple packet message (6:194). The buffer reservation packet transit time, in addition to the probability that the receiving IMP will refuse the incoming message because of the unavailability of sufficient buffer capacity, increases the network connectivity time before the message is even transmitted. Since the multiple packet message cannot be delivered unless all of its packets are available, the probability that one of its packets is delayed due to its unique network path directly affects the message delivery time. This vulnerability to individual packet arrival times is aggravated by the effects of transmission errors, which could impact any of the constituent packets as discussed in the previous paragraph. The transmission bandwidth of the access line between the IMP and the IAC or a network host also determines the size of the packets that can be

received. The TCP determines the maximum size message that can be transmitted based on how quickly this message can be passed from the IAC or IMP to its destination. A high transmission bandwidth on the access line allows larger packets or even multiple packet messages to be transferred. The optimum message size, in number of packets, becomes a tradeoff of high network bandwidth utilization with the multiple packet message against the lower system response times of the single packet message. Another determinant of message size is the function that each message is supporting. The small single packet, as in the character per packet message, is usually generated by human interaction with a terminal to a network host. The lower system response times of the single packet message is preferred in this function. The transfer of files between network hosts is characterized by the large multiple packet messages with the higher response times, which does not have as stringent a response time requirement. The evaluation of a system according to this criteria was accomplished in two ways. One technique utilized the mail session model to demonstrate the number of packets and their size for each system. The other method was a theoretical evaluation based on the specific capabilities of the system and the requirements of the connectivity. An example of the latter technique would be a comparison between a system that generates many small packets against a similar system which generated a few multiple packet messages. The multiple packet is a more network transmission efficient method if the response time requirement is large. If the response time requirement is small then the full single packet would be the preferred method. The component of the network resource criteria that addresses

the effect of network distance in evaluating alternative topologies is the next item to be discussed.

4.1.2.3. Network Distances

The final network resource which was examined for efficiency optimization is the number of nodes that a packet must traverse to connect a source and destination IMP. With the dynamic routing algorithm of the DDN, the actual paths between two IMPs could vary significantly in less than a minute depending on the delays encountered on each path. Although this adaptability is critical for packet flow control and enduring reliable connectivity through redundant paths, it increases traffic demands on the components (ie. IMPs and inter-IMP trunks) of the various paths. This forces the user to access the network at an IMP that is relatively closer (in number of connecting IMPs) to his destination host IMP to reduce the probability of long multinode network traversals with the resulting delay. Another aspect of this problem was the network usage cost reimbursement plans which the DCA is considering. There is one plan to charge a flat rate per network user kilopacket regardless of connectivity through the network. Although this idea requires a minimum amount of accounting system development, it does not provide an incentive to the users to consider more efficient uses for the network. An alternative plan allows all network access charges to be minimized if the accessed host was also connected to same IMP or a neighboring IMP as the the user. A flat rate would apply to all kilopacket accesses beyond this criteria. Both tariff plans provide an incentive for more efficient packetizing of information to reduce many small packets to fewer larger packets. To

minimize network expenses, a user would access the network as close as possible to the destination network host and communicate with large packets, if possible. The resulting effect of this cost reduction technique would be a localization of its communications and also possibly the adoption of a more transmission efficient packet size. Since there is no user's tariff in operation at this time, the above local/distant tariff plan was used during the evaluation to demonstrate its affect. The final criteria under the network resource efficiency is the ability of a system to meet specific response time requirements which are discussed in the next paragraph.

4.1.2.4. System Response Time

The man machine interface has many parameters that have to meet human standards such as size, display intensity, and control access. The most critical parameter; however, is not physical but psychological. System response time is defined as the "Interval between an event and the system's response to that the event" (18:18). According to behavioral psychologists, the system response is essential to the acceptance of the event by a human operator. One reason for this statement is the users's expectancy of a response. In communications, such as a conversation, a response, either audio or visual, is expected within four seconds before the delay becomes unnatural. Another reason for the criticality of system response time is the apparent "sense of completion" or "closure" that characterizes human activities and thought processes. This is due to the short term memory requirements which have a limited time constant. An individual utilizes short term memory, much like a buffer, for information on his current efforts and then dumps the

short term memory contents upon notification of the completion of this current effort. Ease of distraction, which bounds the length of time that an item remains in short term memory, increases with response time. This problem is particularly acute when engaged in a complex problem analysis which fills the short term memory and then system response is high. The combined psychological effects establish an effective upper threshold for system response between two or three seconds for interactive work. System interactive response times on the INFOMAIL/DDN result between the time it takes for an entry at the keyboard for the system to echo this character to the user's display providing necessary psychological feedback. Between these thresholds mental efficiency decreases because the distraction or mind wandering rate is high. On the other side, too fast a system response can be considered annoying to some slow thinking individuals because he believes that it psychologically forces him into a quick response, which is out of his character. Some systems provide a delay to avoid this problem (13:64-68). System response time is an expensive network parameter to optimize because it requires inefficient use of network bandwidth, as previously described. After considering the evaluation of various systems, the following paragraphs address the characteristics of the user/mail system interaction and its effects on the network.

4.1.2.5. User/Mail System Network Characteristics

The above network responses to the various types of communications traffic can now be applied against one specific user application, electronic mail. The following section portrays the network resource characteristics of electronic mail on the DDN.

4.1.2.6. Mail Generation and Editing

The network resource characteristics of mail composition and editing are a combination of interactive, query/response, and file transfer traffic characteristics with the specific details dependent on where the mail generation and editing are accomplished. In all cases, the electronic mail host configuration commands and generated mail message header information, ie. addresses, subject, etc. result in a few small packets indicative of interactive and query/response actions between the user and the mail host. As stated previously, the interactive actions require a short response time while query/response has a larger system response time margin. The actual transmission of the text relies on the network access technique utilized. The terminal access method can be characterized by many small single packets with the typical TAC transmission mode, whereas host supported access can generate the text locally on his network host and use file transfer to transmit the text in few large multiple packets to the mail host. If the user of a host supported access desires to generate the text at the mail host his packet characteristics will be the same as the terminal (14:97-98).

4.1.2.7. Mail Transmission

The mail that has to be transmitted to another mail host is characterized by the file transfer traffic pattern with a few large packets or multiple packet messages. If the mail recipient has a mail box on the sender's mail host, then there is no mail transmission required.

4.1.2.3. Mail Manipulation

The mail manipulation functions of reading, discarding, and filing are also dependent on the user's access technique. In a terminal access the mail host transmits mail to the user, to read, as in a file transfer through many large packets while a host supported access is characterized, also through file transfers, by fewer larger packets. The other mail manipulation functions of discarding and filing are mostly interactive actions resulting in many small packets with a low system response time (14:97-93).

4.1.3. User Interoperability

The interface between the user and the INFOMAIL system is the last efficiency criteria that is utilized in the efficiency analysis. It encompasses the system availability and reliability. Availability is the probability that the system is accessible despite the number of users already using it. The reliability of a system is a measure of the reliability of the individual components that make up the system and also the ability of the system to limit the impact of downtimes either from a failure or for maintenance. The evaluation of a system according to this criteria compares its expected availability and reliability based on architecture and hardware/software of its elements. As an example, a distributed architecture topology consisting of independent components has a higher probability of being available for use than a single component system. The optimization of this criteria increases the utility of INFOMAIL to the user.

4.1.4. Summary of Efficiency Analysis Criteria

The overall techniques for the analysis have been provided along with the specific criteria under which the various topologies and components were evaluated. The following chapters apply these techniques and criteria to the INFOMAIL system and to the significant components of the DDN that support the electronic mail functions. The first aspect of the mail system that was analyzed is the topology which is addressed in the next chapter.

V. INFOMAIL Topology Evaluation

5.0. Introduction

This chapter evaluates the efficiency of the topology of the INFOMAIL system in comparison to three alternative mail systems. The criteria of Chapter Four were applied against each system on a representative network model of multiple users with both terminal and host supported network accesses. The results were utilized to establish the prioritization of recommendations, discussed in Chapter Four, to improve the current system. The following chapter addresses the efficiency of the interface between the user and the network when utilizing electronic mail. The following section of this chapter describes the four mail systems which were evaluated.

5.1. INFOMAIL Mail System Topology

The topology of the INFOMAIL system that supports DCA is depicted, on the representative network, in Figure 5.0. This figure indicates the very centralized topology of the INFOMAIL mail system. Because of this centralized control all user oriented traffic, such as mail generation, editing, and manipulation traverses the entire network. The high numbers of packets generated by these functions, as described in Chapter Four, creates a significant load on the network. The specific characteristics of this network traffic per mail function are addressed after the following description of the centralized architecture.

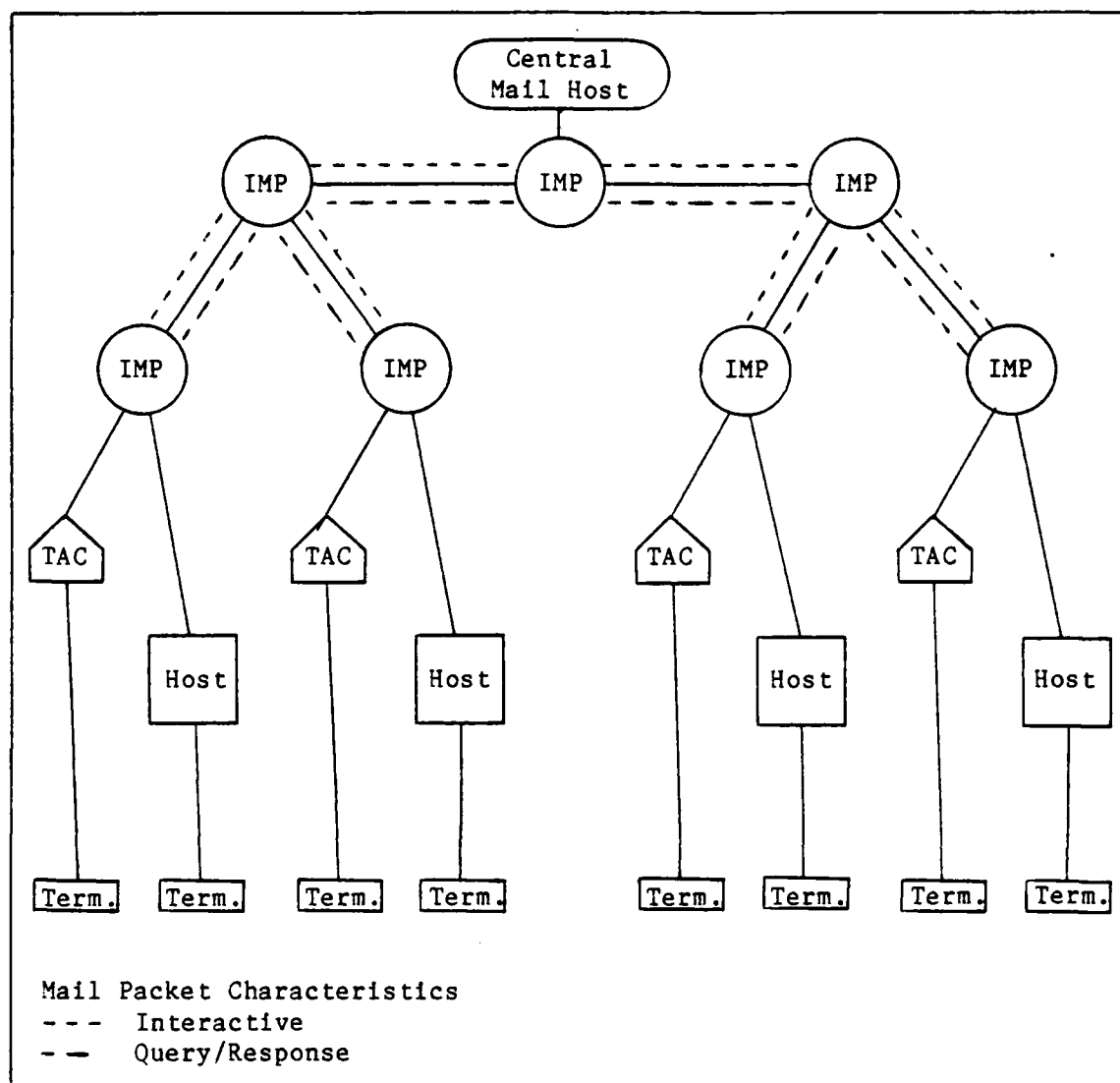


Figure 5.0. Representative Centralized Mail System Topology

5.2. Centralized Mail System Architecture

The centralized system can be described through the necessary data processing hardware and the INFOMAIL software. Also the unique characteristics of the packets generated for each mail function are provided in this section while their impact on the network resources is provided in a later section.

5.2.1. Hardware

A centralized mail host is interfaced into the DDN at one network location. The mail host consists of a C/70 computer with one megabyte of main memory, which contains the INFOMAIL operating system. The secondary storage for user files consists of 300 megabyte disk storage memory and 1 tape drive (19:119).

5.2.2. Software

The core of the system, as briefly described in Chapter Three, is the data base management system and its applications modules, as depicted in Figure 5.1. The user interface module provides user display generation and user I/O for the operating system while the other modules perform the text generation (Document Preparation), mail functions (Mailer), and filing/viewing (Document Server) (14:51).

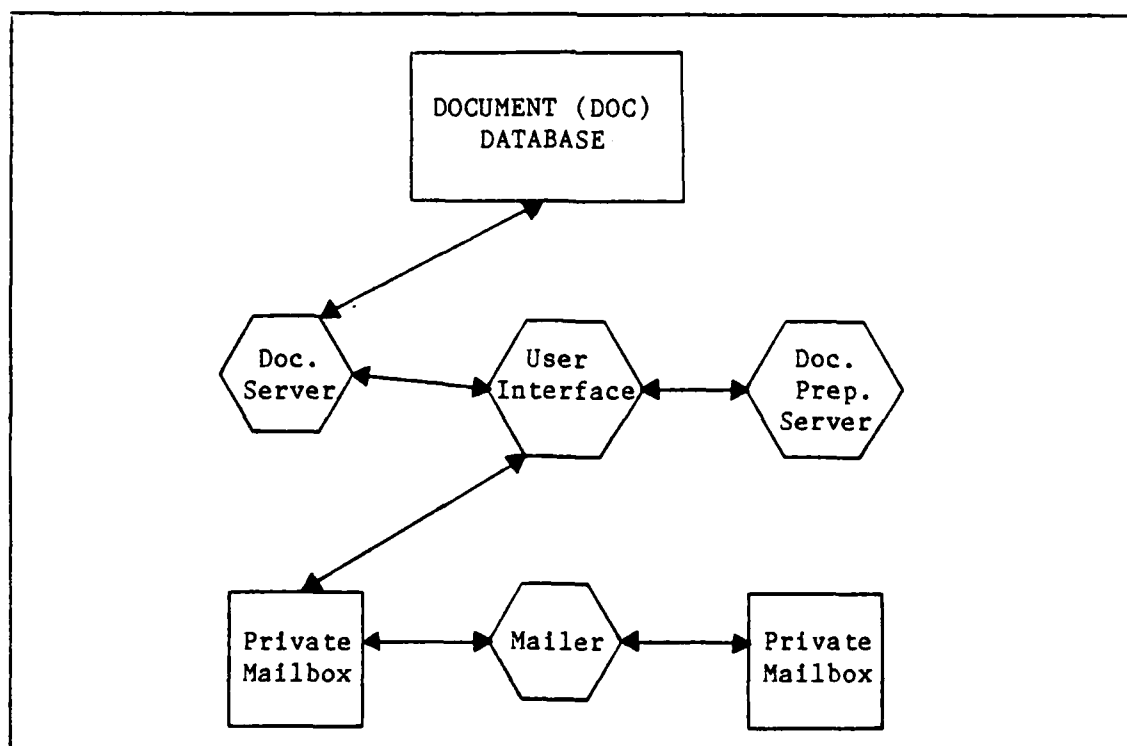


Figure 5.1. INFOMAIL Software Architecture

5.2.3. Packet Characteristics

A mail system's impact on the network is dependent on the traffic generated between the mail system components. The traffic, in packets, between the various users and mail hosts for the centralized system have the characteristics depicted in Figure 5.0 and described in the following paragraphs.

5.2.3.1. Mail Generation and Editing

The host supported mail generation function for this representation is accomplished locally, which provides a relatively short response time to the user. The locally generated mail is then transferred, as seen in Figure 5.0, via the network, as a few large packets as in a file transfer to the mail host for mailing or storage. In the terminal access configuration where the mail host was utilized for mail generation and editing, the interactive and query/response traffic pattern resulted in a combination of small and large packets.

5.2.3.2. Mail Transmission

Mail transmission between mail hosts, as described in the previous chapter, is in a few large packets or even multiple packet messages. There are no mail transmission requirements if a mail recipient has a mail box on the sender's mail host.

5.2.3.3. Mail Manipulation

The mail manipulation functions of reading, discarding, and filing are characterized by a combination of both small and large packets indicative of interactive and query/response actions. The small packets

represent the user transmissions to the mail host to activate the various manipulation commands. The response from the mail host are a few large packets of text for reading. If the user is host supported then the reading function may consist of a file transfer to this host, which requires less interaction and fewer packets with the mail host than a user terminal access.

5.3. Distributed Electronic Mail System Topology

An alternative to the centralized electronic mail system topology is a larger geographical distribution of electronic mail hosts to support the users in distinct areas. A possible implementation of this architecture is depicted in Figure 5.2. The mail host locations, indicated in the figure, were optimized to provide relatively short network access lines to the users for mail generation and manipulation, at the same time provide minimum connectivity, in terms of numbers of IMPs traversed, between mail hosts for mail transfers. The mail hosts are also placed to cover user communities of common interest to keep inter mail host transmissions reduced. A user that is not a member of that community may still use this mail host, if it is the closest to his location. The packet distribution, as seen in Figure 5.2, indicates the transfer of mail using large transmission efficient packets between mail hosts. The less efficient smaller packets, indicative of interactive mail generation and editing traverse a limited portion of the network. The specifics of this network traffic and the mail host architecture are to be discussed in the following section.

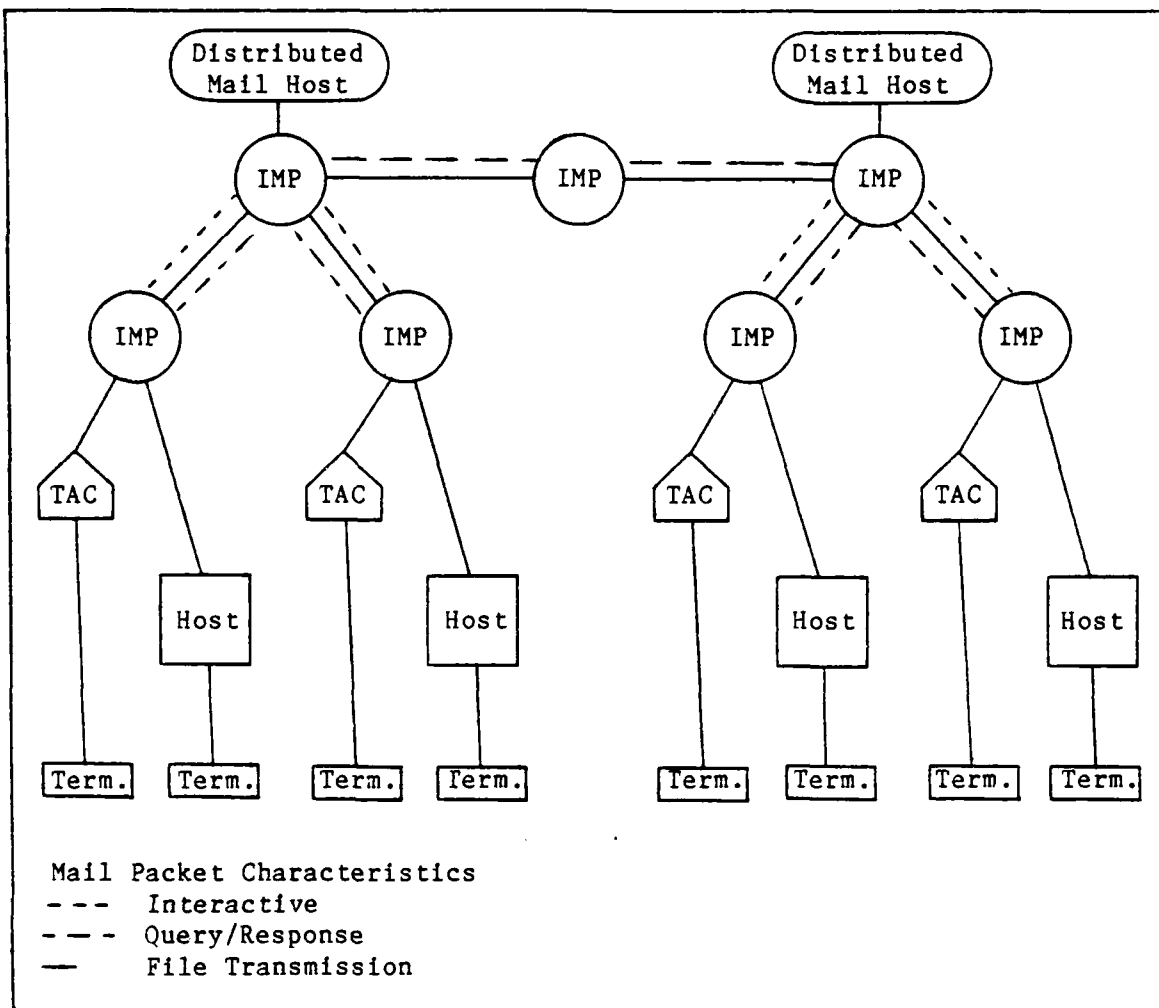


Figure 5.2. Representative Distributed Mail System Topology

5.4. Distributed Mail System Architecture

The above mail system concept is supported with the following hardware and software in addition to the specific network resources for each mail function. Because the distributed mail system is a variation of the centralized system, the differences in hardware and software are minor. The packet characteristics; however, resulting from mail operations, are different.

5.4.1. Hardware

The supporting hardware for the distributed mail host is similar to the centralized system but scaled down to meet the requirements of its small number of users. This specifically results in smaller capacity storage media and a central processor which is required to support fewer users simultaneously. Access lines to the supporting IMPs are also sized to meet this lower requirement.

5.4.2. Software

The mail host operating system is similar to the centralized system with a few modifications possible to reduce the impact of the increased inter mail host traffic. The mail program may be optimized to include the "mail bagging" concept which consolidates all the mail from its users destined for a particular mail host and then transmits them efficiently, as large packets or as multiple packet messages. In addition, either the "mail bags" or mail, in general, can be held temporarily and transmitted during a period of minimum traffic on the network. These concepts can also be utilized on the centralized mail system but are currently not implemented (14:5-6).

5.4.3. Packet Characteristics

The distributed mail system packet characteristics through the network are similar to the previously described centralized system, but because of the mail host dispersion, the packet traffic is not as concentrated. Specifically the packet traffic is distributed by function in the following way.

5.4.3.1. Mail Generation and Editing

The packet characteristics for creating mail are not different from the centralized system. Terminal interaction results in multiple single character packets, while host supported users generates fewer large packets indicative of a file transfer. The significant difference between the two mail systems is that there is less traffic per mail host and less network nodes to traverse to gain mail host access, which keeps the inefficiencies of the interactive mail generation to a minimum.

5.4.3.2. Mail Transmission

For the distributed mail system there is a significant increase in inter mail host transmissions over the centralized system. The specific characteristics of these transmissions are dependent on the mail host software options utilized. The "mail bagging" and minimum network load techniques, as previously described, provide a network efficient means to transmit the information, at a determined time, in large packets. Even if neither option is utilized, the system transmits the individual's mail in large packets as soon as possible.

5.4.3.3. Mail Manipulation

The packet characteristics for mail reading and filing do not change from the centralized to the distributed systems. This means that a combination of small and large packets result from the interactive and query/response patterns of this function. The only difference between the two mail systems is that the distance, through the network between the user and the mail host, is less in the distributed mail system, than the centralized system.

5.5. Layered Electronic Mail System Topology

The best qualities of both the centralized and distributed mail systems can be realized in a hybrid of both. The system design and functional location of the hybrid or layered mail system is depicted in Figure 5.3. A centralized file storage facility maintains large user files, such as documents which are generally not accessed very often in comparison to electronic mail messages. This centralized facility also provides internetwork mail gateway access, responses to mail system inquiries, and software and hardware supervisory control over a distributed system of mail processing hosts supporting local user communities. The distributed components of this layered architecture supports the user's mail access, generation, reading, discarding, and transmission in addition to file storage facility access. Received mail is stored at the mail processor until read and stored or discarded. Each user has limited storage capacity at the mail host processor and excess files are stored at the central file storage facility. The user's immediate access files, such as INBOX and OUTBOX are stored at the mail host processor, while his FILES are retained at the central facility. The network provides user access to the distributed mail host processors and connectivity between the processor and the file storage facility.

The system optimizes network transmission efficiency by limiting highly interactive and inefficient communications to local areas, like the distributed architecture, within easy access to users. This distribution provides the necessary low system response times for the

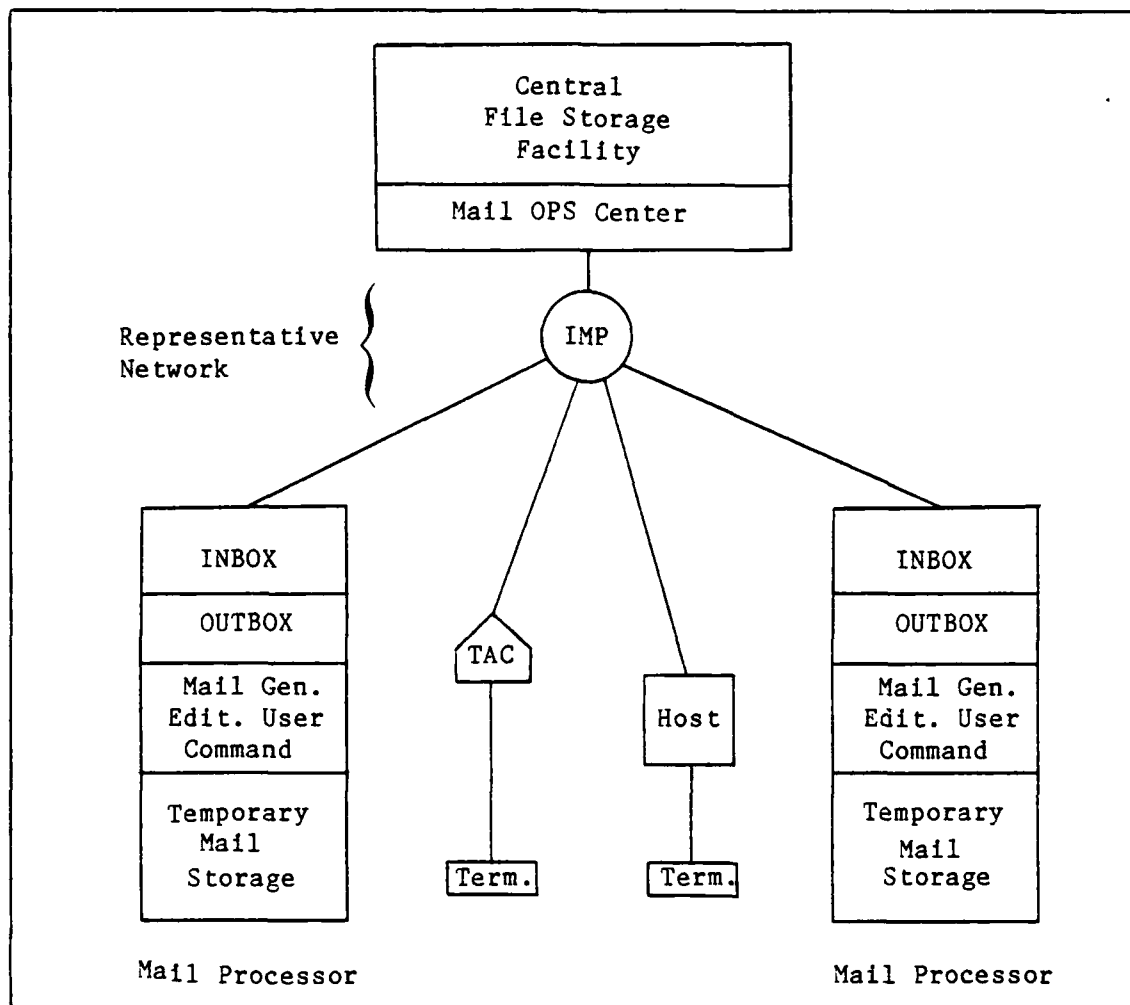


Figure 5.3. Layered Mail System Function Allocation

interactive work. More efficient but less time responsive communications traffic traverse the network between the mail host processor and the central storage facility. The representative system connectivity for the layered mail system is depicted in Figure 5.4. The mail host processors are distributed within separate user communities or at locations that can service concentrations of users. This connectivity provides relatively short network access lines to the users and minimum network connectivity to other mail host processors and the file storage facility. The mail host processors can be physically

located alongside the local IMP, if possible, to reduce facility support and provide a short access line. The following section describes the specific hardware and software necessary to support the layered system in addition to the required network resources.

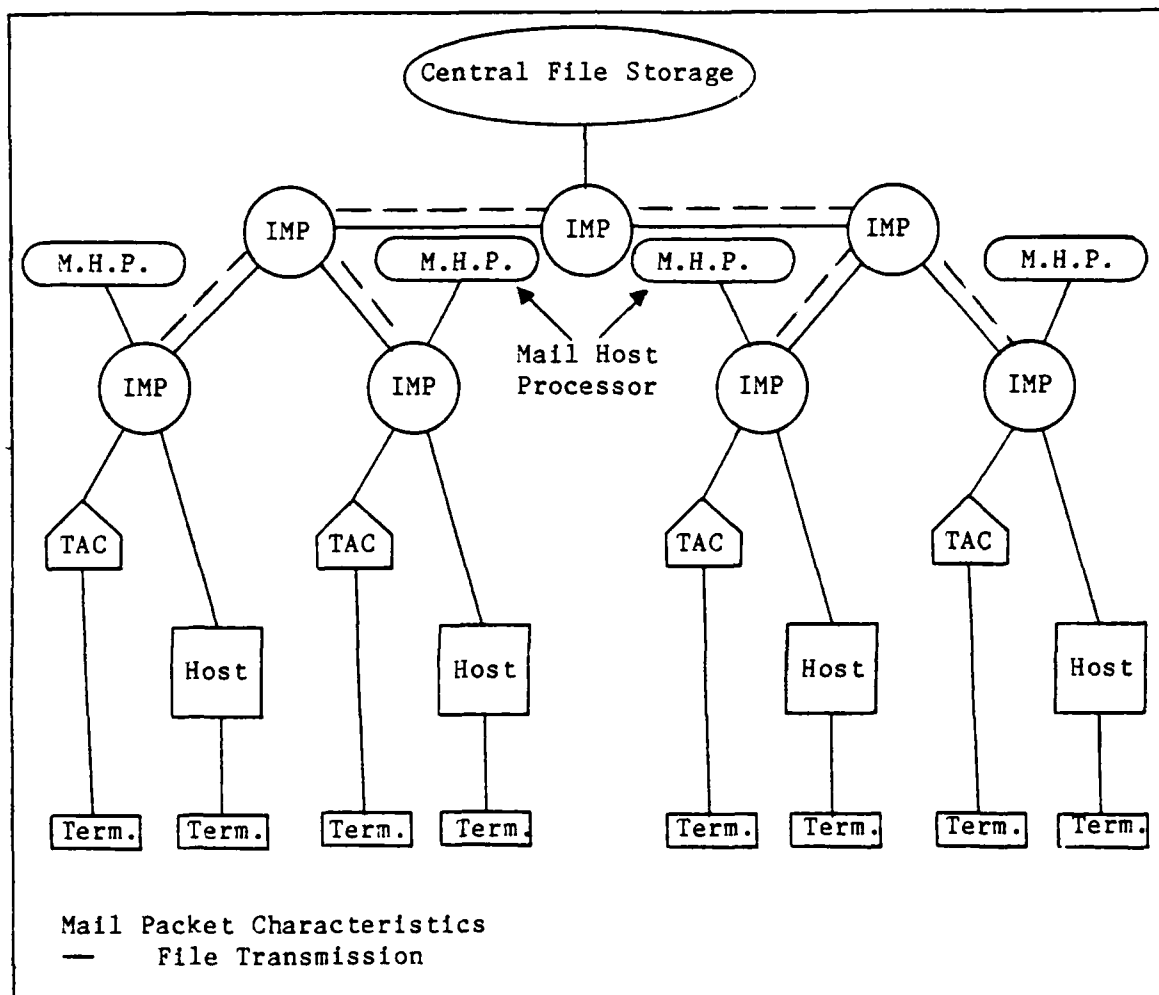


Figure 5.4. Representative Layered Mail System Topology

5.6. Layered Mail System Architecture

The above mail system concept is described through its unique hardware and software in the following paragraphs. In addition, the unique characteristics of the packets generated for each mail function

on the layered mail system are also described below.

5.6.1. Hardware

The computer hardware for the file storage system consists of basically a database management oriented system with sufficient access ports to permit multiple line sharing with several mailhost processors in addition to a large capacity secondary storage media. The mail host processor is designed for unattended, multiple access, high reliability, fault tolerant operation. It is also engineered for component redundancy with automatic switchover, graceful degradation, and remote software loading. The C-30 IMP packet processor demonstrates the necessary hardware for the mail processor. The storage media for the mail processor has similar attributes and is sized to permit sufficient mail storage for its users in addition to temporary storage for mail awaiting transfer.

5.6.2. Software

The software configuration for the layered mail system is a variation of the mail operating systems previously described. The file storage facility operating system can only be accessed by mail host processors to perform the file database management functions. The mail host processor software contains the user interaction and mail modules in addition to a database management system. Since the mail host processor storage capacity is limited, a storage hierarchy is needed to offload excess mail back to the central file storage facility. The software also includes self checks, similar to the IMP software, to ensure its reliability. The mail program can be optimized to include

the "mail bagging" and optimum usage mail transfer concepts for both mail to other mail processors or to the file storage facility.

5.6.3. Packet Characteristics

The layered mail system, because it is an optimization of topologies between the centralized and distributed systems, has packet characteristics similar to the previous systems but distributed differently. This section addresses the packet characteristics of each mail function on the layered mail system.

5.6.3.1. Mail Generation and Editing

This function generates packet characteristics identical to the distributed system. The inefficient, network wise, terminal interaction results in many one character per packet transmissions between user and mail host processor. The proximity, in number of nodes traversed, of the user and mail host processor localizes this inefficiency, even more than the distributed system. Host supported users have a few character per packet transmissions with the actual generated mail being transmitted from the host to the mail host processor in large efficient packets, in a file transfer.

5.6.3.2. Mail Transmission

The packet characteristics between mail host processors and also between the mail host processor and central file storage facility are dependent on the transmission software options in the mail processor and the central file storage facility. As previously described, the mail host processor may use the "mail bagging" concept or the minimum network usage techniques to reduce the inter mail host processor and central file

storage facility traffic. If these options are not utilized the difference is that packets are transmitted as soon as they are ready.

5.6.3.3. Mail Manipulation

This capability varies the packet characterization most from the centralized and distributed systems. Mail reading of locally stored mail at the mail host processor is the same as the two previous systems. Reading of mail or a file at the central file storage facility; however, results in the transmission of several large packets from the central storage to the mail host processor. The mail host processor then provides the material to be read to the user, as if they were locally accessed in the method described previously. Mail storing can have several possible packet characterizations depending on the destination of the file. The commands to the mail host processor are interactive and query/response patterned with multiple small and large packets resulting, regardless of user access technique. If the user elects to retain mail or a file at the mail host processor and adequate storage capacity has been provided, there are no additional commands necessary. To discard the mail, requires a few simple commands, resulting in a few small packets. A decision by the user to store the file or mail at the central file storage facility results in packet characteristics similar to those generated by the mail transmission functions.

5.7. Local Mail Host System Topology

The final configuration to be examined in this analysis is the complete distribution of mail hosts down to the user's locations. This concept was based on discussions with DCEC personnel on a microcomputer

mail host. Figure 5.5 depicts two possible architectures for this mail system. One configuration integrates the mail function into an existing information system by connecting it to a network interface processor which contains the necessary DDN protocols. Thus the existing information system becomes the local mail host with the mail interface processor as its DDN mail transmission/reception port. The alternative configuration utilizes a stand alone microcomputer based mail host to support the local users. The highly reliable unattended system is installed in the user's facilities or within local dial up access line distance to a community of users. Also since the equipment is within the user's facility, limited maintenance can be accomplished by the user. This unit provides all the mail support functions for mail generation, editing, reading, discarding, and filing to these users without a requirement for the users to access the network. When inter mail host communication is required for mail transmission out of the local area, the local mail host accesses the network through a TAC or an IMP to provide connectivity. The topology for this mail system is depicted in Figure 5.6. The network access for both mail host configurations was assumed to be through the TAC for the representative topology. A central mail operations center is maintained to answer user inquiries, transmitted as electronic mail, to provide usage accounting, coordinate software upgrades, and dispatch maintenance teams. This system basically incorporates the electronic mail host into the ever expanding office information system or through the local area network. The required hardware and software necessary to support the layered mail system, in addition to the network resources, are to be described in the following section.

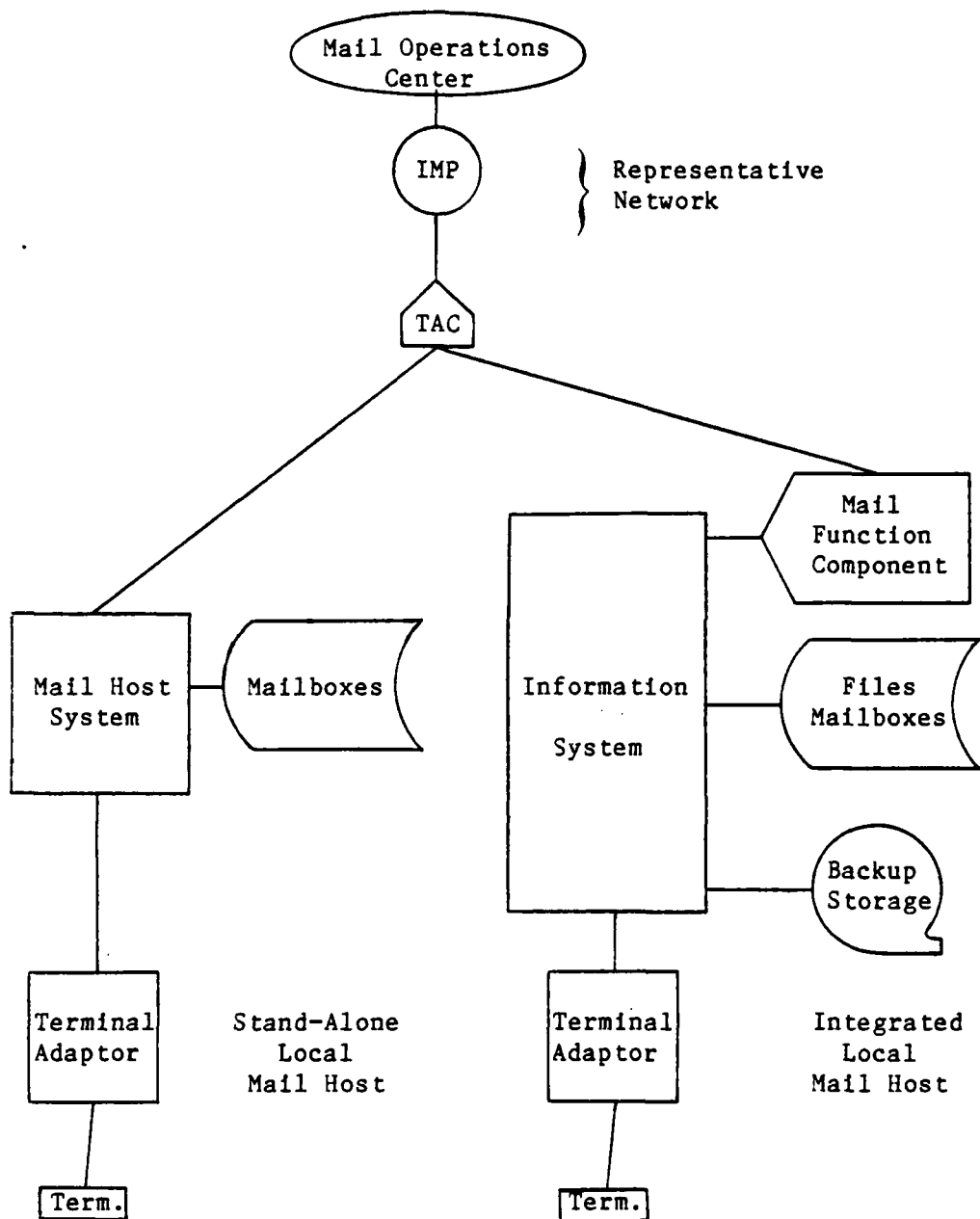


Figure 5.5. Stand Alone and Integrated Local Mail Host
System Configurations

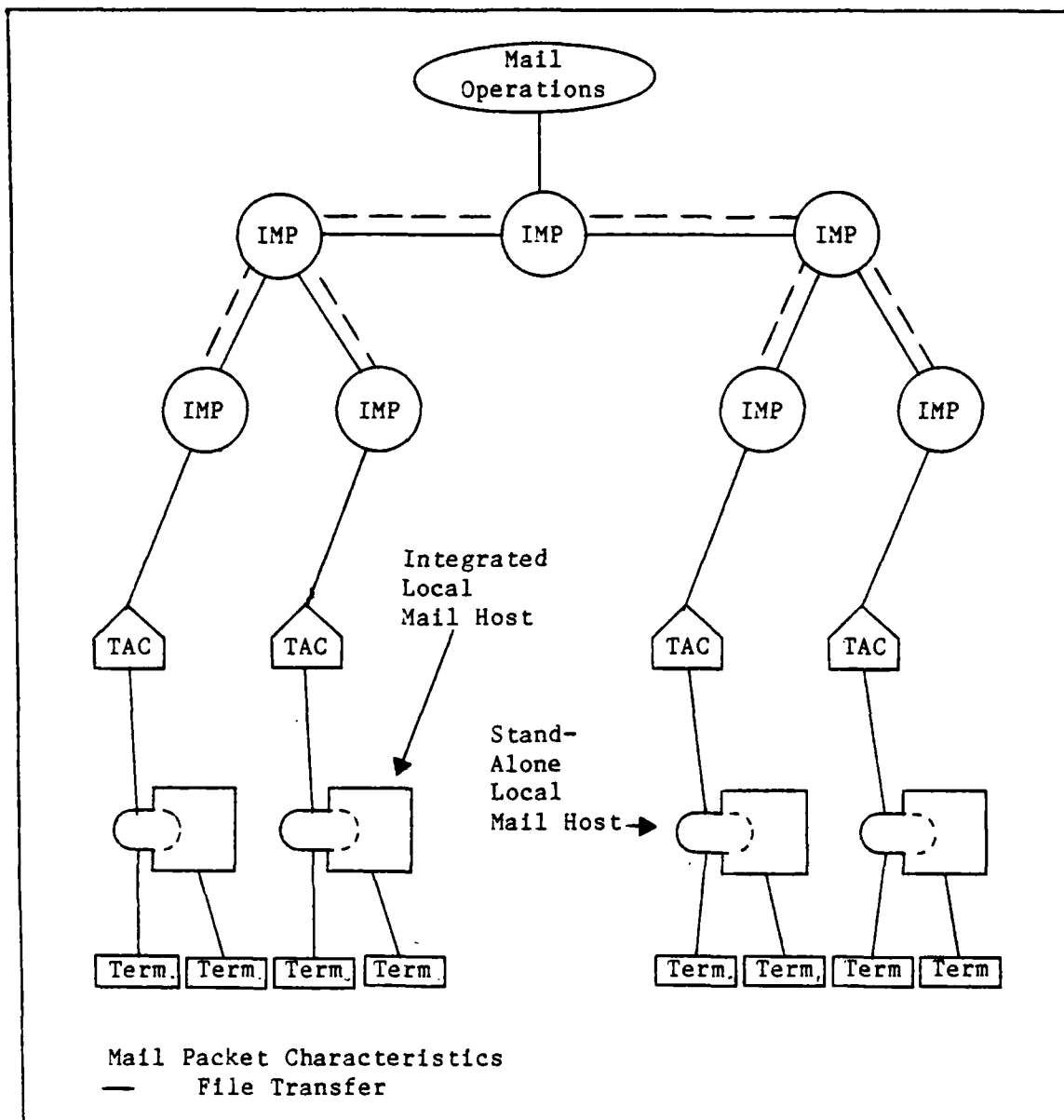


Figure 5.6. Representative Local Mail Host System Topology

5.8. Local Mail Host System Architecture

The unique hardware and software necessary to support the local mail host system concept, in addition to the required network resources are described in the following section.

5.3.1. Hardware

The required hardware has two possible configurations, as seen in Figure 5.5, depending on its interfacing techniques. A stand alone system is similar to the centralized system but on a size scaled to meet a small number of users. The mail host may also be an additional communication processor to an existing information processing system to provide connectivity and protocol support with the network. Whichever technique is implemented, a central processor, to provide mail host control, user interaction, data base management, and network communications support, is required along with a storage media. In addition, the unattended operation requirement includes the necessary component redundancy, self loading capability, and fault tolerance described in the layered mail system hardware description in paragraph 5.6.1. The network access lines are adequate to meet the projected inter mail host transmission requirements of this community. Mail host access lines and their required control, which was accomplished by the network in the previous mail systems, are now the responsibility of the mail host or the existing office information system depending on which configuration is implemented.

5.3.2. Software

The extent of the software for the local mail host system depends on the hardware that supports it. If the mail host is an additional function of an existing information system then it may utilize the data base management capabilities of the system it is integrated into. The portion of the original software suite of the centralized system that is utilized by the integrated mail function system is therefore dependent

on the existing information system and its interface capabilities. The mail host can be reduced to a network communications processor which contains the communications protocols translation modules. The stand alone alternative system requires the same software architecture outlined for the centralized system. In either case the software reliability must be high to support the unattended operational requirement which means that fault tolerance and self checking capabilities are required from the software.

5.8.3. Packet Characteristics

The local mail host system, regardless of configuration, has the same network characteristics. By its architecture, it is a user localized system made to interface with the user through local access lines and not through the network. Mail generation, editing, reading, discarding, and filing therefore do not require network access. Inter mail host transmissions are the only function that require network connectivity.

5.8.3.1. Mail Transmission

The inter mail host transmissions between the mail hosts, for the local mail host system are the same as the previously described systems. Large multiple transmission efficient packet messages with high system response times characterize the network traffic from this function. The "mail bagging" and optimum network usage techniques can also be applied against the requirement to improve its utilization of network resources.

5.9. Topology Comparison

The topologies of the four mail systems have depicted their

differences in packet characteristics and function allocation. this section determines the efficiency of each mail system according to the criteria of Chapter Four. This in turn leads to a prioritization of recommendations based on the magnitude of the inefficiency in the current system that they improve and also through the amount of resources required to implement them. Chapter Seven summarizes the results of the evaluation and the recommendations. The evaluation technique and its rationale are discussed with the evaluation criteria. Figure 5.7 is a composite depiction of the four mail systems to provide a common representation of their unique topologies. This composite mail system is only a tool for highlighting the mail system differences for each evaluation criteria and should not be considered a hybrid combination of the four topologies.

5.9.1. Financial Resources

The evaluation of the four mail system topologies utilized their representative connectivities depicted in Figure 5.7 to determine the amount of equipment required to implement each system. The following paragraphs provide the financial resource criteria prioritization for the recurring costs which entail the development and procurement of the mail system and the non recurring costs which cover the activated mail system's operations and maintenance support.

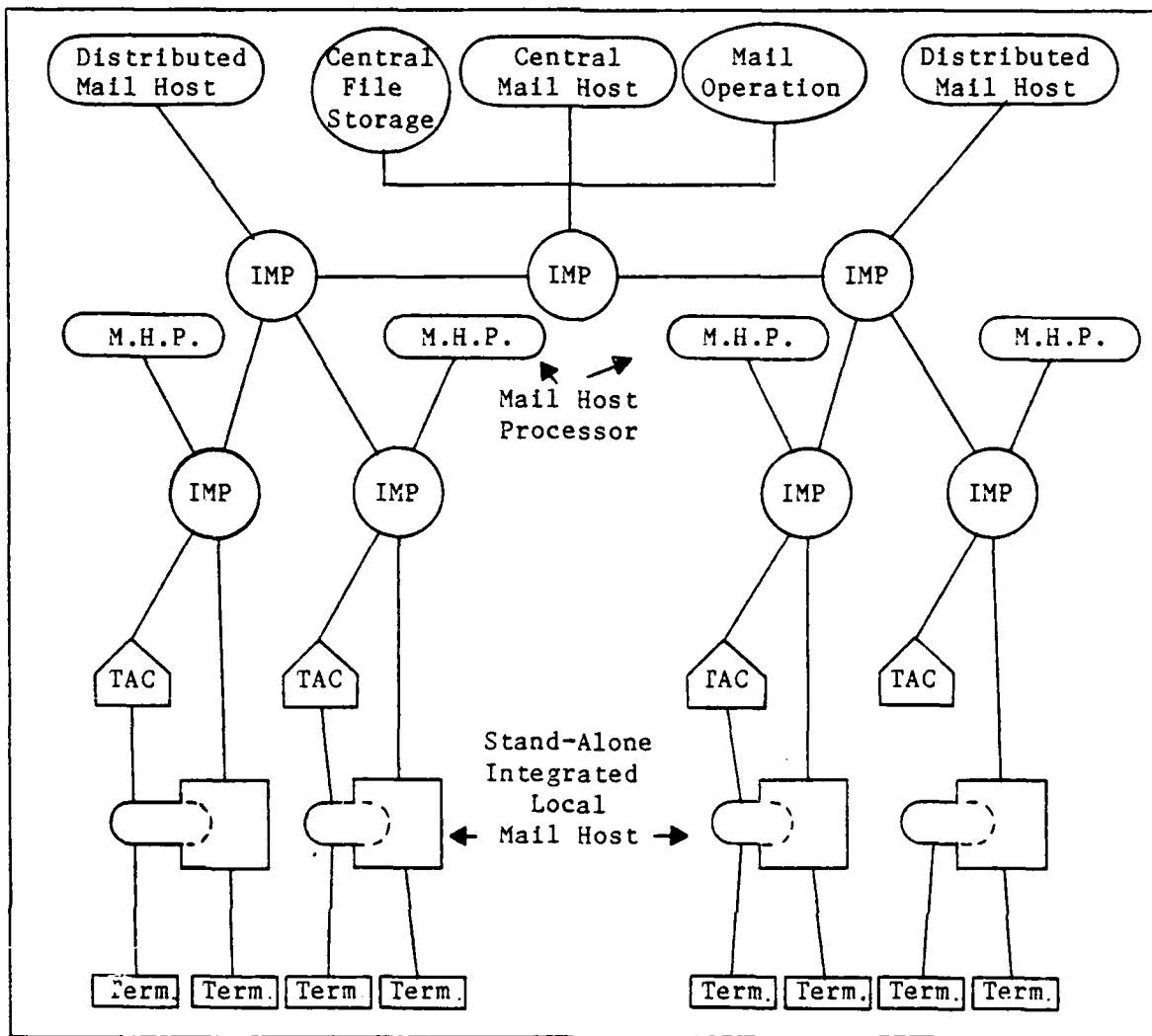


Figure 5.7. Composite Mail Systems on the Representative Network Model

(NOTE: There is no functional interaction between mail systems)

5.9.1.1. Mail System Topology Prioritization Based on Non Recurring Costs

The evaluation of the mail systems according to their non recurring costs is based on an estimate of the up front investment cost necessary to engineer the system and develop the mail host's hardware and software. In addition, the mail system has to be procured and installed

with the required facility support. The essential cadre of operations and maintenance personnel along with their training are also required prior to operational cutover. With these considerations the prioritization of mail systems from the lowest cost to the highest cost resulted in the following.

1. The centralized INFOMAIL mail system has the lowest non recurring costs because of its single network location requiring one facility and one mail host. In addition, its simple data base management mail host requires no development.
2. The distributed mail system is projected to have the next lowest non recurring costs for similar reasons to the centralized system. A minimum number of and simplicity of the mail hosts keeps the facility support and equipment procurement cost below the layered and the local mail host alternatives. Since this system is merely a smaller version of the centralized system, there are also no development costs.
3. The third mail system in the non recurring category is the local mail host system. This is due to the costs required to develop a highly reliable unmanned system and engineer a somewhat universal interface to the user's equipment. The other mail systems had the advantage of the DDN as the provider of the standard interface. Also the procurement of multiple pieces of equipment with their installation into a user's facility further justifies this ranking of this mail system.
4. The layered mail system is the fourth or most expensive mail system in required non recurring costs because of its projected higher

development costs in comparison to the local mail host system. The development of the highly reliable unmanned mail host processor requires a significant investment in comparison to the three previous mail systems. The procurement of this unique hardware and software, installing it, and providing facility support for five locations, including the central storage facility, also requires significant funding.

5.9.1.2. Mail System Prioritization Based on Recurring Costs

After a system is operational, the day to day costs of supporting it become apparent. These costs entail the salaries of all the system support personnel, facility support, in addition to the procurement of spare parts. Under these categories the mail system topologies can be prioritized from the lowest to the highest recurring costs in the following ways.

1. The local mail host topology can provide the lowest operations and maintenance costs because of its unmanned highly reliable mail hosts and single mail operations center coupled with the user providing this support.
2. The centralized mail system is the next least expensive alternative in this category due to its single operations and maintenance facility. Because the mail host was not specifically designed for the same level of highly reliable unmanned operations as the local mail host and the layered system, its support staff is larger. In addition, the facility support of this system was higher than the previous system because of the incorporation of the local mail host within the user's facility.

3. The layered mail system is the third mail system in this category because of its unmanned highly reliable mail host processors. The manning of the central file storage facility, in addition to the deployable maintenance teams covering numerous locations, determines this relative position behind the local mail host and centralized mail system.
4. The most expensive alternative was the distributed mail system because of its two locations of manned equipment. In addition, this equipment does not have the same high reliability of the local mail host and layered mail systems. The two distributed mail hosts require more operations and maintenance personnel than the single mail host system.

5.9.2. Financial Resource Summary

The above analysis justifies the prioritization of mail systems from least to most expensive. In Table V.O., the results indicate that the current INFOMAIL mail system has the lowest one time investment costs but that the local mail host has the lowest operations and maintenance costs.

Table V.O. Prioritization of Mail System Topologies Based on the
Required Financial Resources.

<u>Expense</u>	<u>Non Recurring Costs</u>	<u>Recurring Costs</u>
Least	1. Centralized	1. Local Mail Host
	2. Distributed	2. Centralized
	3. Local Mail Host	3. Layered
Most	4. Layered	4. Distributed

This information coupled with a relative weighting factor, provided by DCEC personnel, was utilized to establish a prioritization of mail system topologies according to their financial resource requirements. Minimizing recurring costs was given a relative value of 8/10, with the denominator representing the maximum value possible. Consequently, reducing non recurring costs had a relative standing of 2/10. The specific breakdown of mail systems with both their recurring and non recurring costs evaluated with the DCEC weighting factor is provided below.

1. Local mail host least expensive
2. Centralized
3. Layered
4. Distributed most expensive

5.9.3. Network Resources

The comparable evaluation of the four topologies within the network resource categories can be seen in how each mail system utilizes the packet for communications and the effect of the packets, generated from each mail system, on the network. Figure 5.7 coupled with the packet characteristics for each mail function, that were addressed in Chapter Four, provides an evaluation model to determine the specific network resources required by each system.

5.9.4. Network Resources Topology Evaluation Technique

The evaluation of the mail systems was conducted by utilizing the most common network access technique, the terminal, and the user mail

session model determined for the design of the Movements Information Network (MINET). This mail session model was determined through BBN and user requirements surveys which translated existing Automatic Digital Network (AUTODIN), TELEX, and telephone communications into electronic mail requirements (19:21). This was used to calculate the number and size of packets resulting from typical mail generation, editing, reading, discarding, and filing functions as accomplished by a teletype terminal (see appendix for specific results). The specific packet characteristics are dependent on several variables. One is the source of the message where the mail host transmits multiple characters per packet and the teletype, with the TAC in its normal character at a time mode, transmits a single character per packet. Another consideration is the echoing from the mail host back to the teletype to confirm character receipt. Finally the single largest determinant of packet size is the size of the information block that is being transferred. The analysis determined the number of characters per packet for each network transmission between the teletype and the mail host. The node distances between the various components of the mail systems represents the average number of network nodes required to provide connectivity for that particular mail function, which indicates the magnitude of the network that is influenced by the particular packet characteristics generated by each function. As an example, the terminal that must connect to the nearest distributed mail host must traverse at least two nodes with the highly transmission inefficient packet characteristics of this interactive traffic. The average packet utilization rate for each mail system under the various mail functions provides an indicator of

the effectiveness packet in utilizing the network capacity efficiently. It is calculated as the ratio of the amount of user information each packet carries over the maximum capacity of user information for the packet. The network resource comparison also included the inter mail host transmissions between mail hosts. This evaluation consisted of a comparison of average node distances between mail hosts as an indicator of the extensive network traversals required by each mail system. Specific packet utilization rates for the inter mail host transmissions are very high in comparison to user generated traffic. The number of packets per mail transmission was approximated at 27 packets (1600 characters in 26.3 packets which can carry 61 characters per packet) based on the 1600 character piece of mail generated during the mail session.

5.9.5. Network Resource Topology Evaluation Results

The above results demonstrate the severity and expanse of the transmission inefficiencies of each mail system on the network. It certainly shows the benefits of the different system architectures in localizing, as seen in node connectivity of Figure 5.7 and the node distances of Table V.1, the large number of inefficient interactive traffic from the generation/editing/posting of mail from a terminal.

Table V.1. Mail System Network Resource Evaluation

Mail System Topologies												
	Central			Distributed			Layered			Local		
	Node	Pkt	No.of	Node	Pkt	No.of	Node	Pkt	No.of	Node	Pkt	No.of
	Dis	Util	Pkts*	Dis	Util	Pkts*	Dis	Util	Pkts*	Dis	Util	Pkts*
Gen/ Edit/ Post	3	3.45	3733	2	3.45	3733	1	3.45	3733	0	0	0
Read/ File/ Discard	3	35.85	77	2	35.85	77	1*	35.85	77	0	0	0
Inter Mail Trans	0	-	27	2	-	27	3.3	-	27	3.4	-	27
NOTES: * Packet totals do not include TCP acknowledgements. ** If files at the central file storage are required then network connectivity is 3.												

Large traverses of the network by packets of any size increases the network congestion. This problem increases with large numbers of packets. The centralized mail system, as seen in Figure 5.7, has the greatest impact on the network because of the distance that the packets must travel during a mail operation. This problem is exasperated at the node which supports the mail host when more than one terminal conducts mail operations. The other topologies have the benefits of distributed architectures to reduce the network congestion. The only difficulty with the alternative topologies is that increased distribution between

mail hosts increases the node distance that electronic mail must cross. With the exception of the inter mail host transmissions, the packet utilization rate and numbers and sizes of packets are a function of the user's TAC transmission mode and terminal and not the mail system. The node distance along with the packet utilization rate constitute the significant variables in the evaluation of the four topologies. A low packet utilization rate coupled with a large node distance indicates a relatively severe impact on the network. To optimize a topology, by minimizing the impact on network resources, the low packet utilization rate must be in conjunction with a small node distance. The effects of the proposed network tariff against each mail system can be determined in the nodal distance value. As originally stated, all connectivity equal to or less than two nodes results in a lower usage tariff. A simplistic indication of expected system response for each mail system can be obtained through the number of nodes that should be traversed. A lower number should indicate a lower system response time. A realistic system response time is dependent on the traffic on the IMPs and communications lines connecting the user to the mail host. Also the processing speed and load on the mail hosts themselves must be taken into account to determine a specific response time value.

5.9.6. Network Resource Summary

The prioritization of the alternative mail system topologies was accomplished through the minimization of their required network resources. As stated in the previous paragraph the optimum topology reduces the impact of both the low packet utilization rate and large numbers of packets by localizing their effect with small node distances.

This strategy was used to prioritize the mail systems as seen in Table V.2. Also stated in the previous paragraph, each mail function has its characteristic packet utilization rate along with numbers of packets which are functions of the TAC and the terminal used in the mail operation.

Table V.2. Prioritization of Mail System Topologies based on Minimized Node Distance per Mail Function. (Prioritized from lowest number of nodes to highest)

<u>Mail Op.</u>	<u>Mail System</u>	<u>Priority</u>
Gen/Edit/Post	1. Local Mail Host	Lowest
	2. Layered	
	3. Distributed	
	4. Centralized	Highest
Read/File/Discard	1. Local Mail Host	Lowest
	2. Layered *	
	3. Distributed	
	4. Centralized	Highest
Inter Mail Host Transmission	1. Centralized	Lowest
	2. Distributed	
	3. Layered	
	4. Local Mail Host	Highest

* NOTE: Assumes files at local mail host processor.

The local mail host has the lowest network resource requirement for every mail function except for the inter mail host transmissions where

it is the highest. The level of architecture distribution from highest to lowest correlates with the mail generation/editing/posting and mail reading/filing/discarding functions and inversely correlates with the mail host transmission mail function. Through the "mail bagging" and network minimum usage concepts the network impacts for mail transmission can be minimized with that assumption. The prioritization, from best to worst, of mail system topologies based on minimum network resources results in the following:

1. Local Mail Host.
2. Layered.
3. Distributed.
4. Centralized.

This provides additional justification for the mail system topology recommendations at the conclusion of this chapter.

5.9.7. User Interoperability

Prioritization of the user interoperability comparison was accomplished according to the requirements that must be met by each mail system. Specifically, the prioritized categories are mail host availability and system reliability. Availability addresses the probability of being able to access the mail host. If a large number of users attempt to simultaneously access the same mail system, which has a limited capacity, the result could be a blocking of service to some users. The system availability is a function of the simultaneous user access capacity of the mail system in addition to the network connectivity. System reliability is an indicator of the system's ability to prevent mail host failures and lessen their impact. This

capability is based on the reliability of the individual components of a mail operation such as the terminal, access lines, mail host etc. in addition to the network connectivity. It's also dependent on the number of users denied service by a failure in any component of the mail operation. The evaluation of the mail system topologies was based upon an examination of their architectures and their designed reliability. The following paragraphs address the analysis of the mail system topologies according to their system availability and reliability.

5.9.7.1. System Availability Evaluation

Based on the evaluation of the alternative mail system topologies according to their system availability, the following mail system prioritization, from highest to lowest, resulted.

1. The local mail host topology has the highest availability because of its deployment strategy of multiple units to cover localized communities of interest. The actual availability is based on the local access lines and not upon the network at all.
2. The layered mail system is the next highest mail system also because of its deployment strategy. The positioning of the mail host processor near an IMP that supports a geographically localized area minimizes the number of possible simultaneous accesses in comparison to the distributed and centralized mail systems.
3. The third topology according to the system availability category is the distributed mail system. Its architecture reduces the possibility of service blockage due to simultaneous accesses below the centralized system but not as well as the local mail host and layered mail systems.

4. The last mail system topology, in providing high system availability, is the centralized system. This is based on the fact that a single mail host to cover all users increases the probability of users not being able to access the mail host, simultaneously.

5.9.7.2. System Reliability

The ability to minimize the number of users affected by mail system or DDN failures coupled with the system's designed reliability, are the evaluation goals for the system reliability prioritization of mail system topologies. This evaluation resulted in the following mail system ordering from highest to lowest.

1. The local mail host has the highest system reliability because of its distribution to the smallest group of users. A failure in the network connectivity merely disables the inter mail host transmissions but still allows the other mail functions. A mail host failure only impacts those users that are locally supported by it.
2. The layered mail system topology has the second highest mail system reliability through its distribution of mail host processors which minimizes impacts to users due to both network and mail host processor failures. Its reliance on the network reduces its reliability below the local mail host but its highly reliable hardware and software place it above the distributed and centralized mail system topologies.
3. The distributed mail system is the next mail system in this ranking of system reliabilities. Although the distributed mail system

utilizes the same hardware/software as the centralized system its distribution reduces the users impacted by a mail host failure.

4. The centralized mail system is the lowest evaluated alternative for system reliability because of its architecture. Its single location is a failure point that would affect all the users.

5.9.8. User Interoperability Resource Summary

The evaluation of the mail system topologies according to their projected system availability and reliability resulted in the analysis in the previous paragraphs and are summarized in Table V.3.

Table V.3. Prioritization of Mail System Topologies based on User Interoperability Resources. (Prioritized from highest to lowest Availability/Reliability)

Priority	Availability	Reliability	Availability/Reliability
High	1. Local Mail Host	1. Local Mail Host	1. Local Mail Host
	2. Layered	2. Layered	2. Layered
	3. Distributed	3. Distributed	3. Distributed
Low	4. Centralized	4. Centralized	4. Centralized

5.10. Topology Comparison Conclusion and Recommendations

The analysis determined the points of inefficiency in each mail system. The current centralized system evaluation indicated that it has the most inefficient use of the network resources with the lowest availability/reliability features in comparison to the alternative systems. Its efficiency in use of financial resources is a

consideration if low cost expansion is required and the network and user interoperability resource inefficiencies are acceptable. These conclusions and the prioritized mail system topologies addressed in the previous paragraphs were evaluated against a DCEC provided relative weighting factor against each criteria. This permitted DCEC personnel to establish the final prioritization of mail system topologies based on their combination of the relative merits of each alternative's financial, network, and user interoperability efficiencies. The user interoperability criteria was rated as the most important with a relative weight of 5/10, with the denominator 10, being the maximum. The network and financial resource were considered to be 4/10 and 1/10 respectively. This relative weighting reflects DCEC's interest in providing maximum mail service to as many users as possible with minimized network resource impact. The financial resources necessary to accomplish this task are not considered a significant issue in comparison to the other efficiency criteria. The following recommendations are based on the weighted prioritization of mail system topologies according to the magnitude of the inefficiencies they correct from the current centralized system.

1. The use of the local mail host will improve the utilization of network resources and also the system availability/reliability. Its development costs are offset by the above improvements in addition to lower operations/maintenance cost than the current system.
2. The layered mail system has the next lower level of network resource and system availability/reliability improvements in

comparison to the local mail host. Its development and operations/maintenance costs are higher.

3. The distributed mail system has the least improvement in network requirements and system availability/reliability. Although its development costs are lower than the two previous alternatives its operations/maintenance costs are higher.

Prioritizing recommendations according to the amount of financial resources necessary to implement them results in the following.

1. The distributed mail system has the lowest implementation costs coupled with the least improvement over the current system. Its operations/maintenance costs however, are the highest of all the alternatives.
2. The local mail host has a higher implementation cost than the distributed mail system but lowest operations/maintenance cost. It also has the most significant improvement in network resource utilization and system availability/reliability than all the alternatives.
3. The most expensive alternative to implement is the layered mail system. Its operations/maintenance costs are lower than the distributed system and it has the second lowest network resource requirements with the second highest availability/reliability, which still makes it a viable alternative.

The two critical issues to consider in deciding which alternative to choose is time and requirements. Development time is needed for the alternatives and user requirements can increase significantly. The centralized system can handle increments of additional users but a large

number would overwhelm this capability. This study did not evaluate future requirements, but if current network expansion is an indicator, these additional requirements will arrive without much forewarning. The distributed mail system should be deployable with the shortest lead time whereas the layered and the local mail host will require substantial development leadtime. The local mail host system could benefit from the current onslaught of information systems, by assisting in the development of the interface standards with industry. Unfortunately, the typical DoD user tends to purchase off the shelf commercial equipment and then try to "bend" it to meet DoD standards. With the advent of information systems throughout the DoD, the justification for developing the DDN local mail host is realistic. This chapter has addressed the mail system architecture and how it can be optimized against the efficiency criteria. The following chapter evaluates the techniques for accessing the INFOMAIL mail host through the DDN.

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EFFICIENCY ANALYSIS OF THE ELECTRONIC MAIL SYSTEM
(INFOMAIL) ON THE DEFEN. (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. K R KAVANAUGH
DEC 84 AFIT/GE/ENG/84D-40 F/G 9/5

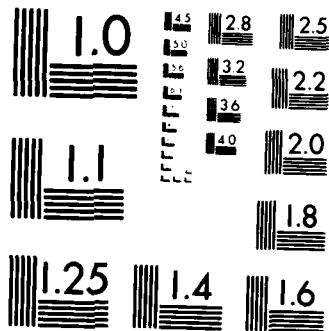
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

VI. User/Mail System Interface Efficiency

6.0. Introduction

The evaluation of the INFOMAIL system on the DDN has addressed the hardware that is unique to the mail system. The utilization of that mail system can only be accomplished through its interconnection with the user through the DDN. This interfacing of the user to the mail system is the focus of this chapter. Certainly one of the most critical components in the DDN is the user's I/O device. It is also the most non standard component since it is provided by the user and is not engineered into the system. This latter statement provides one of the more expensive problems because the DDN attempts to generate a universal interface for all user I/O devices. This chapter provides an evaluation of the various electronic mail I/O devices and interface techniques to determine the efficiency of each one along with its alternatives. The efficiency criteria of Chapter Four was used to determine the recommended alternatives. The following chapter consolidates the conclusions of the efficiency analysis of the INFOMAIL system and prioritizes recommendations to improve the current system. Before the evaluation of the different I/O interfaces, a review of the basic I/O requirements is provided.

6.1. I/O Requirements

The interaction between the host's application software being accessed on the network and the human being is through an I/O device. The range of I/O devices is quite large, but specifically for electronic mail the alphanumeric keyboard display terminal provides the exact human

to INFOMAIL interface. The terminal presents the system image to the user and can have significant impacts on the effectiveness of the application software on the network. The capabilities and efficiency of the entire system, as in response time and data throughput, could be constrained by an inefficient terminal system. The terminal display has improved and added capabilities, such as terminal editing, have been provided through microprocessor support of the terminal, yet the basic function of time responsive alphanumeric I/O have remained the same. The following section describes the various INFOMAIL access techniques. The last section addresses the INFOMAIL supported host.

6.2. User Access Techniques to the INFOMAIL System

The interface between the user and the network to the INFOMAIL mail host can take place in two ways. There is the Terminal Access Controller (TAC), which provides an inexpensive way for a user with a terminal to access the network and the INFOMAIL system. The other method is for a user at a network host to utilize that host as either a network interface to access the INFOMAIL system on a distant network host or as an INFOMAIL host for direct non network access. The following section describes and evaluates the terminal access and host supported access techniques.

6.3. Terminal Access Techniques to the INFOMAIL System

Terminal access to the INFOMAIL network host is conducted through the TAC, which provides the protocol support and network interface device. The following section evaluates the TAC and representative terminal configurations for efficiency in interfacing with the INFOMAIL

system.

6.3.1. TAC Concept of Operation

The interfacing of multiple terminals, with a myriad of different transmission speeds, is a significant effort. The TAC must provide the user support to ensure access validation, negotiate a connection through the communication's protocol to a network host, and then become transparent to the actual transmissions. The TAC outputs a universal message that varies with length chosen by the user. The IMP views the TAC as another host as it packetizes the messages and forwards them to the destination host. The Figure 6.0 depicts the major functional components of the TAC.

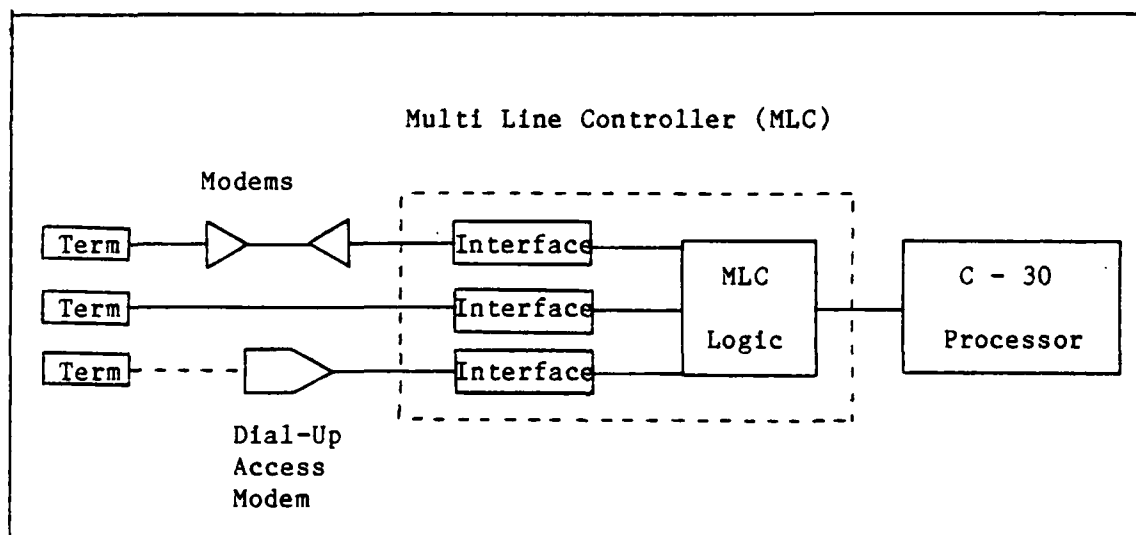


Figure 6.0. TAC Functional Components

The Multiline Controller (MLC) provides the communications interface between the terminals, connected through the access lines to the C/30 processor. The MLC contains the logic which disassembles input

characters from terminals and transfers them to the C/30 memory buffers. Consequently, it also transfers and assembles output characters from the C/30 memory buffers to be transmitted back to the terminals. The number of characters per packet is chosen by the user during the TAC access session. The MLC also contains the line interface units which provide the physical communication controls of the TAC ports to match the transmission speeds to the terminals. Upon initial contact with the TAC, the MLC collects data on the terminal operating parameters and stores them in the C/30 memory. The C/30 processor, through the TAC software, sequentially removes the data from the memory and applies the TELNET, TCP, IP, and network access protocols to establish a connection with the destination host and then transmit messages through the IMP. The return route from a host to a TAC is similar but the host, if it is utilizing the BBN UNIX operating system, transmits a group of characters together in one packet. The BBN UNIX operating system on the mail host maintains a storage buffer containing all the characters to be transmitted back to the terminal; at a certain time interval it transmits the buffer contents together. The TAC stores the characters until they have been sequentially transmitted to the user's terminal (6:359-362). The various transmission modes for the TAC are addressed in the following paragraph.

6.3.2. TAC Transmission Modes

The flexibility of the TAC has included selectable transmission modes which have the potential for improving transmission efficiency. The TAC has the following software selectable modes to transmit messages to the IMP in various sizes.

1. Character at a Time -- This is the normal mode of operation for the TAC.
2. Line at a Time -- The TAC transmits to the remote host whenever a linefeed is received.
3. Message at a Time -- The TAC transmits to the remote host whenever an end-of-message character is encountered.
4. Word at a Time -- This function is not too available in the TAC software at the present but will be available by January 1985. It causes the TAC to transmit when it detects a space, as in the completion of a word, or a .5 second interval without an input.
5. Transmit every 3 -- The TAC transmits the contents of its buffers after 3 number of characters.
6. Transmit Now -- The TAC immediately transmits the contents of its buffers immediately upon receipt of this command. This is not a permanent condition and the TAC reverts to the original transmission mode after executing this command.

The TAC software also allows the selection of whether the TAC should send an echo locally back to the user's I/O device, thus saving the transmission bandwidth of the return path, or have the echo originate from the host as normally done (9:34). Although the TAC provides several transmission mode options, its interface through the network to the mail host has a few inefficiencies which are discussed along with possible solutions in the next section.

6.3.3. TAC Transmission Inefficiencies

The total overhead of these communications protocols at the output of the IMP is 520 bits per packet, with 160 bits for TCP, 160 bits for

IP, and 200 bits for IMP-IMP subnet information. Here lies the significant waste in transmission efficiency. With the TAC in its normal character at a time transmission modes. Terminal generated traffic is interactive with one character depressed at a time resulting in the 8 bit ASCII character requiring 520 bits of overhead for an information transfer rate (8/528) efficiency of 1.5%. This problem is further compounded by the need for an echo from the network host back to the user's I/O device, to confirm character reception.

6.3.4. TAC Proposed Transmission Plans

The solution to the problem requires more than just a selection of a more efficient transmission mode and echo plan than is currently utilized. Operating systems and application software on the network hosts have been configured to utilize some of the single control character at a time command modes. Changing transmission modes would impact these functions. Because the TAC becomes transparent to the communications it passes, it cannot differentiate between a command or a text character. The first wide scale application of a non character at a time transmission mode and local echo was done on the DDN subnetwork, MINET, in Europe (20:6-6). Each IMP is connected through 9.6 kbps trunks instead of the 56 kbps trunks of the rest of the DDN. This decreased bandwidth necessitated a more efficient use of the network transmission media. The MINET used a line at a time transmission mode with the TAC providing the local echo. This configuration also required the modification of the INFOMAIL software and UNIX operating system to allow local echoing from the TAC and to prevent the selection of the "CBREAK" mode of operation. Unfortunately, the MINET had to revert to a

character at a time mode of operation because of MINET software faults and was therefore not available for data analysis. A revised software system, in the line at a time and local echo mode, is being finalized and should be activated on the MINET by January 1985.

6.3.5. Remote Application Controlled Echoing (RACE) and Remote Controlled Terminal Echo (RCTE)

Other attempts to reduce transmission inefficiency through a dynamic adjustment of transmission and echoing modes are the RCTE and RACE plans. Both would be applied in the TELNET protocol application layer when responsibilities between the user TELNET and the server TELNET are being negotiated. Basically the TAC would provide the local echo when simple character echoing was required, which also provided the user a short response time. Character echo generation from the host would be initiated when more demanding computation, such as a control character, was necessary. In addition, the TAC would retain the locally echoed characters until such time as a character requiring host computation is generated. At this time the TAC would transmit its contents in a large packet. The potential improvement in network bandwidth efficiency is significant in these dynamic transmission and echoing mode plans, as long as the user is not using a substantial number of characters requiring host echoing. The RCTE, which was an earlier algorithm of the above concept, was actually implemented on the TIP, but it was not utilized by many host systems and suffered from early TIP software problems. The RACE concept has not been thoroughly evaluated to determine its full capabilities and limitations (21).

6.3.6. Recommendations

The need to improve the transmission efficiency of the MINET, because of its lower network bandwidth, is obvious. As the MINET begins supporting additional users, the character at a time transmission mode with remote echo will begin saturating network trunks and IMPs causing increased system response time. The line at a time, with local echo plan can be evaluated on the MINET in the near future to determine its effectiveness for application on the DDN. At the same time, the RACE concept and new word at a time transmission mode should also be evaluated to determine its capabilities and limitations. The evaluations should take place along the following guidelines.

6.3.7. PAC Evaluation Objectives

To demonstrate the effectiveness of these transmission efficiency enhancements, data should be collected, as a minimum during a representative time period, utilizing the 3BN packet statistics software. It is important to establish baseline performance in the character at a time and remote echo mode prior to evaluating the line at a time and remote echo enhancements. Specific data categories are the following for peak and average periods.

6.3.7.1. Circuit Utilization

This item indicates the percentage of the time that a communications channel is active. It is specifically calculated by dividing the average bit rate of a link by its capacity. A high circuit utilization rate of about 60% can create high queuing delays in the IMP which degrades interactive terminal usage because of increased system

response (22:13).

6.3.7.2. Packet Length Distribution

This metric provides an indicator of network transmission efficiency with the larger packets being more efficient, in their transport of information.

6.3.7.3. Round Trip Delay

This statistic indicates the system response time it takes a source host to receive an indicator that the destination host is ready for a new message. This is particularly important in human generated interactive terminal traffic (22:16-18).

6.3.7.4. Operational Performance

The impact on user applications of either non character at a time or local echo modes should also be collected to assess their limitations in an operational environment. The following paragraph outlines the method by which the above data should be analyzed.

6.3.8. Evaluation Technique

The comparison between the various transmission and echoing modes should easily indicate the performance enhancements and limitations. The expected performance trends of the non character at a time and local echoing modes against the baseline character at a time and remote echo are the following. A decrease in line circuit utilization rate from the baseline should translate into decreased congestion and queuing delay on that trunk's IMPs. The distribution of packet sizes should change from baseline performance, to indicate an increased percentage of larger

packets. This shift translates into a more efficient use of the network transmission bandwidth because a larger packet conveys more information than a smaller packet with the same amount of overhead. The larger packet size, unfortunately creates a slight increase in packet network traversal time, in comparison to the baseline, as seen in the round trip delay data. The results of the operational performance tests along with the increase in system response times must be weighed against the transmission efficiency improvements and the decrease in circuit utilization rate to justify a decision to incorporate the technique in the DDN. The expected performance of these TAC transmission efficiency improvements on the DDN is provided below.

6.3.9. DDN Implementation

The potential improvements in transmission efficiency for the MINET are greater than in the DDN for the following reasons. The MINET was developed as a heavily interactive electronic mail system in comparison to the mixture of host and terminal traffic on the DDN. Therefore there will not be the same level of improvement in transmission efficiency in the DDN. Also the currently low circuit utilization rate and system response time of the DDN should not experience a significant decrease in non character at a time and local transmission mode.

6.3.10. TAC Interface Summary

The TAC has provided low cost but effective access to the network resources. To improve the efficiency of the TAC's interface with the network requires a fundamental change in the protocols which dictate how terminals-TACs-network hosts communicate. This change will cause user

software impacts but the resulting improvement in the network transmission efficiency will benefit the entire network. The terminal that interfaces with the TAC is another source of inefficiency. The following section compares three terminal configurations according to the criteria in Chapter Four.

6.4. Terminal Network Access

The next logical point in the system analysis is the user interface device. This function is provided by the terminal. Although there has not been any essential change in the terminal's basic function of providing alphanumeric I/O to the user, there are a wide range of different support capabilities available. This section addresses three representative terminals and their relative efficiency in the use of the financial, network, and user interoperability resources described in Chapter Four. The results compared the three terminals and generated recommendations which could improve the overall efficiency of terminal network access for the INFOMAIL application.

6.4.1. Teletype Terminal

The simplest terminal to be discussed is the mechanically driven teletype, which had its forerunner in early digital communications systems and was one of the first man machine interfaces. The teletype converts the alphanumeric keyboard input to an ASCII coded eight bit word, with a parity bit, into alphanumeric characters on its display, which is provided by a serial printer. The TAC provides the necessary network interface protocols and buffers.

6.4.2. Intelligent Terminal

The definition of an intelligent terminal is "a keyboard/crt terminal to which a user programmable processor has been added" (6:179). The evolution of the intelligent or processor controlled terminal resulted from the need to improve the obvious inefficiencies of the teletype. The way to accomplish this was to distribute logic to the components of the network, particularly those preparing data for network transmission. The terminal was a logical choice because it could preprocess the input data into a more transmission efficient format. The range of capabilities of these systems vary considerably but a few of the more significant functions are:

1. End to end error checking can be incorporated into the terminal much like the host to host error checking in the TCP protocols.
2. Off network line text generation and editing utilizing a secondary storage media could be performed like a host network access.
3. Text compaction to reduce total bits required to transmit a message. This could simply mean that data is only transmitted from the terminal when the carriage return or linefeed is activated and then the entire message is transmitted. It could generate a unique code which more efficiently represents the input data.
4. Syntax checking could be done locally instead of through a network host.
5. Terminals can be interleaved to allow several terminals to use the same access line more efficiently.

6.4.3. Personal Computer

The advent of the personal computer has made more logic and storage

memory available than the previously described intelligent terminal. The personal computer could be defined as a multifunction microprocessor based computer system with some limited capabilities of the host computers. In the role of a terminal, the personal computer provides a low cost alternative to network access through a network host with an IMP. The personal computer, because of its increased technical capabilities of larger storage memory and programmability, has increased capabilities in addition to those listed for the intelligent terminal. The flexibility of the personal computer allows it to locally generate and edit mail using a variety of different software packages that provide user support such as spelling checking and different terminal emulations.

6.5. Terminal Network Access Comparison

The user currently provides the DDN I/O device. An evaluation of the capabilities and limitations of each of the three terminals, previously described, determined the inadequacies in current interfacing techniques for each terminal configuration along with the recommendations to improve them. Also the combined prioritization of terminal configurations, according to the above efficiency criteria, outlines the justification to influence future terminal procurements. The evaluations are accomplished through a logical mination of the financial resource requirements and availability/reliability of each terminal. In addition the specific network resource requirements for each terminal were determined through the application of the mail session model. The financial resource requirements evaluation is the first portion of the analysis that is addressed.

6.5.1. Financial Resources

This section analyzes the relative financial resource prioritization between the three terminal configurations. This was based on the evaluation criteria described in Chapter Four. The differences between the intelligent terminal and the personal computer in this criteria become negligible and therefore the prioritization was conducted between the teletype and the intelligent terminal/personal computer. The wide range of acquisition costs for all three terminal configurations makes a relative evaluation of representative non recurring costs too subjective to be conclusive. The prioritization of terminal configurations according to non recurring costs is a question of the reliability and maintainability of the mechanical technology of the teletype in comparison to the solid state technology of the intelligent terminal/personal computer. The reliability of solid state equipment in a benign environment is higher than mechanical equipment in a similar environment. Also, although the teletype has been a DoD standard I/O device it is being replaced with more up to date solid state intelligent terminals. This evolution jeopardizes the future spare parts and maintenance support for the teletype to a point that the intelligent terminal/personal computer will become the DoD standard I/O device. Based on this logical analysis of the non recurring costs of the terminals, the intelligent terminal/personal computer are the preferred user I/O devices according to the required financial resources. The analysis of the network resource requirements for each terminal is discussed in the following paragraphs. These results together with those of the financial and user interoperability resource

evaluations and recommendations justify the terminal prioritization at the conclusion of this section.

6.5.2. Network Resources

The efficiency differences between the three terminals are significant for the network resource criteria. The capabilities and limitations which were discussed in the terminal descriptions were employed in this section against a theoretical mail session model to determine the exact number and size of their resulting packets. Each terminal configuration was then compared against one another to establish recommendations. The following paragraph addresses the method utilized to determine the network resource efficiency of the terminal configurations.

6.5.2.1. Terminal Network Resource Evaluation Technique

The evaluation of each terminal was accomplished through the application of the MINET mail session model that was discussed in the previous chapter. This model represents a typical user mail host interaction from a terminal. Each terminal's unique capabilities were utilized to reduce their network resource requirements to the minimum. This entailed altering the configuration of the PAC during a file transmission when possible. The access line transmission bandwidth was kept at 9600 bps, the maximum for the teletype even though both the intelligent terminal and personal computer have higher capabilities. The possible configurations for the intelligent terminal and personal computer would have made an exhaustive evaluation of these terminals beyond the scope of this study. Therefore a representative

configuration was chosen, which provides both terminals with storage and local editing capabilities, based on their most prevalent configuration when communicating to the mail host. In this configuration there is no difference in network resource requirements between the two terminals. The evaluation results were summarized into the frequency distribution of packet lengths per mail function which is an indicator of the probability of a packet being a certain length. The longer packets are more transmission efficient than the shorter packets. The packet utilization rate for each terminal was determined to demonstrate the efficiency of the use of the packet as a communications component. The number of packets generated per mail function was also computed for each terminal. This number provides a comparison of the volume of network traffic resulting from each terminal. The actual results of the evaluation are seen in Table VI.0 and are analyzed in the following paragraphs.

Table VI.0. Terminal Network Resource Evaluation Per Mail Function

C	Gen/Edit/Post					Read/Discard/File				
	No.of Pkts	Pkt Length Distribution			Pkt Util.	No.of Pkts	Pkt Length Distribution			Pkt Util.
		1-20	21-40	41-61			1-20	21-40	41-61	
1	3733	98.3	0.08	1.6	3.5	77	64.93	1.3	33.71	35.9
2	330	88.8	0.6	10.6	9.7	77	64.93	1.3	33.71	35.9
(C) Terminal Configurations: 1. Teletype, 2. Intelligent Terminal and Personal Computer.										

Note: Total number of packets does not include TCP acknowledgements which would double the tabulated value.

6.5.2.2. Terminal Network Resource Evaluation Analysis

The above results (see appendix for specific calculations) for the generate/editing/posting of mail show the advantages of the intelligent terminal and personal computer over the teletype in required network resources. The differences are attributable to the off line text generation and editing capabilities of the intelligent terminal and personal computer. The teletype normally operates through the TAC in a character at a time and remote echo transmission mode for entering and editing the text which generates a significant number of short packets. This increases the packet congestion in the network. The alternative terminals utilized their file transmission capabilities to transmit the text of the message through the TAC in line at a time and local echo mode. The packet utilization rate is a more accurate indicator of the transmission efficiency of each terminal configuration. The interactive communications requirements reduce the transmission efficiency of the packet as seen particularly with the online text generating and editing of the teletype. The mail reading/discarding/filing function showed no differences between terminals in required network resources because the off line storage and editing capabilities of the intelligent terminal and personal computer have no advantage in this query/response function. This difference in network resources for each terminal can be readily felt by the user when the usage tariff is applied. Since the rate is dependent on numbers of packets and not their individual size, the higher volume of packets from the teletype session make this user device

an expensive option.

6.5.2.3. Network Resource Summary and Recommendations

The evaluation of the required network resources for each terminal revealed their impacts on the network due to a typical mail session. The teletype terminal required the largest number of packets and utilized the transmission capability of the packet inefficiently in comparison to the intelligent terminal and personal computer. A modification to the teletype to include local storage and editing will improve its network performance considerably. Enhancements in the intelligent terminal and personal computer network resource performance could be realized with the inclusion of the INFOMAIL message format into their systems. This would allow the entire message, not just the text, to be generated locally and then transferred to the INFOMAIL host. These points, coupled with the previously stated advantages of low response times during local mail generation and editing, make the intelligent terminal and personal computer the more efficient I/O devices. Results from the table, coupled with the previously stated advantages of low system response times during mail generation and editing, and lower usage tariff than the teletype, make the intelligent terminal and personal computer the more efficient I/O devices. To complete the analysis of the representative terminals, the evaluation of their user interoperability was also conducted. The results of this evaluation follow.

6.5.3. User Interoperability

The user interoperability criteria, as described in Chapter Four,

addressed the availability and reliability of an item. The availability category is not applicable to the terminal in the same sense as it was applied to the mail system topology evaluation of the previous chapter. In that context, there were many users in competition for a limited resource, the mail host access. The terminal availability is an evaluation of how efficiently it can be used thus reducing the demands on the system that is interfaced to it. In the specific electronic mail role the terminal configurations each had certain capabilities which influenced their required network resources. This aspect addressed the limited capacity of the network but did not take into account the time required to perform the mail functions. Since the mail system has limited access capacity the time that a terminal is interfaced to it increases the probability of another user being denied service. Therefore a terminal's availability is more a measure of the connection time with the mailhost which affects the mail system's availability. The intelligent terminal and personal computer clearly exceed the teletype in lower connection time because of their ability to generate and edit text in addition to reading transmitted mail off line. This latter capability was not demonstrated in the mail function during the mail session because the mail session model required reading in conjunction with filing and discarding. Therefore the intelligent terminal and personal computer are the preferred user I/O devices in the availability category. The reliability of the different terminals was discussed during the financial resource evaluation. This concluded that the reliability of the intelligent terminal and personal computer was higher reliability than the teletype. In summary the user

interoperability evaluation of user I/O devices resulted in the intelligent terminal and personal computer as the more efficient option.

6.6. Terminal Network Access Conclusions and Recommendations

The efficiency analysis of the representative terminals resulted in the conclusion that the teletype terminal had the highest network and financial resource requirements in addition to the poorest user interoperability. Although the user's I/O device is his responsibility, based on the evaluation results, DCA should consider providing incentives to the users to adopt these recommendations. The proposed DDN usage tariff would encourage the use of terminals which could perform lower cost file transfers than interactively entering data would. Between the intelligent terminal and the personal computer the significant difference is that the latter system can be programmed to emulate various terminal configurations or provide other non mail functions in addition to the capabilities of the intelligent terminal. Since the evaluation performance was identical for both terminals this flexibility makes the personal computer the preferred I/O device with the intelligent terminal as the next alternative. The teletype, by its poor performance, is the least desirable terminal. Another alternative is that the teletype can be upgraded with a memory storage and editing device, to bring up its capabilities to the level of the intelligent terminal and personal computer performance. The advantages of this alternative are that the teletypes are already fielded and user will also benefit from a lower usage tariff, in addition to the increased capabilities. The development, acquisition, and support costs of this added component must be weighed in the evaluation of this alternative.

A final alternative, which requires the modification of DDN network hardware and software, would address the inefficiency of the interface between the personal computer and the DDN. A network host can utilize FTP to transfer its locally generated files through the network. An inclusion of this capacity into the TAC or the IMP, along with the required software in the personal computer would improve the efficiency of its file transfers when used to access the network. Again this modification must be thoroughly understood and the future requirements for personal computer access to the network must be evaluated to determine the cost effectiveness of this additional capability.

6.7. Host Supported INFOMAIL Access

Another method for interfacing with the INFOMAIL system is through a local host connected to an IMP. Figure 6.1 depicts the two possible configurations for this case. The following paragraphs provide the specific details of each configuration and the inefficiencies of this INFOMAIL access technique.

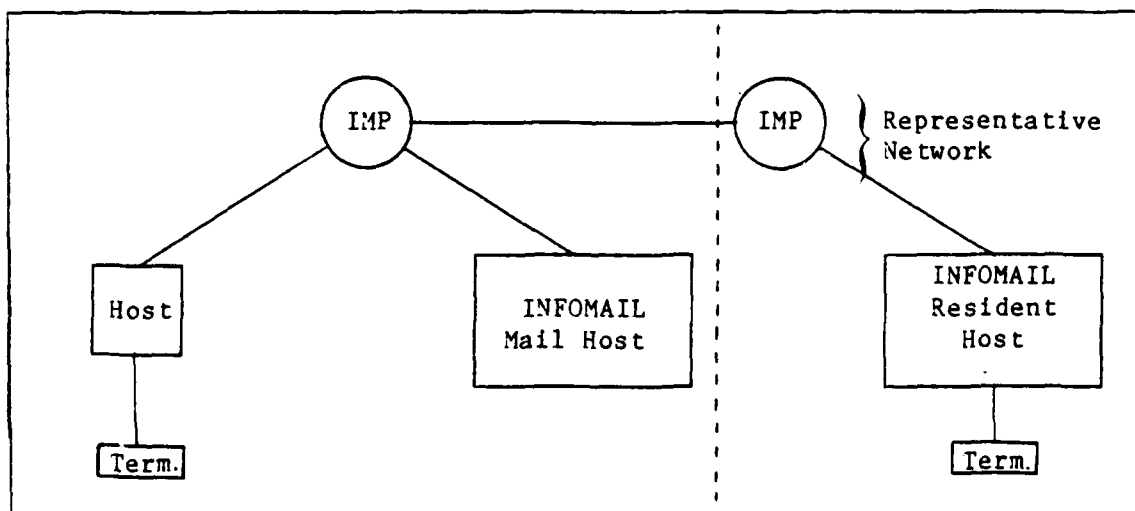


Figure 6.1. Host Supported INFOMAIL Access Configurations

6.7.1. INFOMAIL Resident on the Local Host

The simplest access to INFOMAIL is accomplished through the user's local host if it contains the INFOMAIL software. The INFOMAIL application software is accessed as would any other software package in the software library. The mail session is done locally, without the network, and the mail transmission from the user's host to a distant network host is done through the network utilizing either SMTP for a non INFOMAIL mail system and FTP for another INFOMAIL system. If the recipient has a mail box on the user's host, then the network transmission is not necessary.

6.7.2. INFOMAIL Resident on a Distant Network Host

Network connectivity to INFOMAIL, when it is resident on a distant network host, can be provided through a local network host. The user initiates the communications process in his local host by sending the TELNET, TCP, IP, and network access protocols to open a connection through the local IMP to the destination host. At this point, the local host becomes transparent terminal support to the user's communications unless specifically addressed by the user, as in a file transfer. The traffic therefore from the host to the IMP is the same as if the terminal were connected to the IMP directly (8:83).

6.7.3. Host Supported Network Access Transmission Inefficiencies

When used interactively this communications transparency through the local network host, after the connection to the distant network host has been made, creates a significant transmission inefficiency. Currently, each single character that is input by the host supported

terminal generates single character packets and requires remote echoing from the distant network host. As the analysis of the TAC indicated, this is a waste of network bandwidth, which also results in a high usage tariff. Unfortunately, there are not network host operating as in the TAC such as line at a time, message at a time, and local echoing. The following paragraph addresses a possible solution to the host supported access transmission inefficiencies.

6.7.4. Host Supported Network Access Transmission Efficiency Improvements

If the mail is locally generated, edited, and read, these inefficiencies are minimized to strictly the mail host commands with transmission efficient file transfer of the mail between the local network host and the mail host. Also, as discussed in paragraph 6.3.1., the time interval flow control scheme also improves transmission efficiency for the BEN UNIX supported mail hosts. To reduce the transmission inefficiencies of interactive traffic a modification to the TELNET protocol and the host operating system provides transmission and echoing modes similar to the techniques discussed for the TAC in paragraph 6.3.5. The transmission mode evaluation techniques should also be used to determine the effectiveness of this transmission scheme.

6.8. Host Supported Network Access Conclusions and Recommendations

The locally accessed INFOMAIL host does not require the network for any function other than mail transfers. The use of a local host as a network interface for a terminal is a poor utilization of network bandwidth when the user is operating interactively. One alternative of

utilizing the local host as a more efficient network interface is by incorporating the operating system and TELNET modifications discussed in the previous paragraph. An external interface device, containing the required software, should be an alternative to the modification of the operating system. The projected and recommended DDN usage tariffs would both encourage these modifications.

6.9. User I/O Interface Efficiency Analysis Summary and Recommendations

The user interface with the DDN and subsequently with the INFOMAIL system was methodically dissected and analyzed according to the efficiency criteria of Chapter Four. The evaluation consisted of an examination of each component from the user's terminal up to the supporting IMP, with the exclusion of the communications lines. There was inadequate time to complete the evaluation of the technique utilized to determine the transmission bandwidth of these lines but an observation was made that a more cost effective technique than allowing the users to determine his bandwidth requirements could be made. The evaluation of each component of the user interface varied according to the function of that component. A representative mail session model quantified the differences in required network resources for the different terminals. Also the financial and use interoperability resource requirements for the terminals were determined. A theoretical evaluation of the network resource requirements of the terminal and host supported network access techniques revealed their limitations. The results indicated significant inefficiencies in the use of the DDN to access INFOMAIL. Whether it is a terminal to a FAC or a terminal through a network host, the user/network interface does not

provide the most network transmission efficient means to communicate. It is recommended that the IAC be modified to provide a more network efficient transmission mode. In addition these modifications should also be included in the operating systems of network hosts that support INFOMAIL access. The evaluation of user I/O devices determined that the personal computer was the preferred terminal. The intelligent terminal had the same efficiency as the personal computer but lacked the flexibility of the programming capability. The teletype had the lowest efficiency performance against the evaluation criteria. Recommend that DCA encourage INFOMAIL users to utilize the more transmission efficient personal computer when accessing the network. The usage tariff provides an incentive for the users to adopt transmission efficient terminals or modify their current units to provide local storage and editing capabilities. The results will lower the user's cost and utilize the DDN resources more efficiently. The following chapter will summarize the conclusions of the efficiency analysis and lay out prioritized recommendations to improve the efficiency of the INFOMAIL system on the DDN.

VII. Conclusions and Recommendations

7.0. Introduction

This chapter concludes the efficiency analysis of the INFOMAIL application on the DDN, by summarizing the significant results and outlining the prioritized strategies for implementing the recommendations for the specific inefficiencies noted in the previous chapters. Although these recommendations are not exhaustive and mainly deal with network transmission efficiencies, they were determined to be within the area of DCA's greatest concern with the available time. Nonetheless, the analysis and resulting recommendations for each item were developed in light of their benefits and required resources. The magnitude of these required resources, in a DoD wide program, was determined through prior experience as an Air Force Program Manager in the Defense Satellite Communications System. To implement any of the recommendations, and justify the required resources, the future requirements must be understood. The paragraph following the recommendations will discuss the essentiality of this function.

7.1. Conclusion

The results of the analysis of the INFOMAIL mail system indicated inefficiencies in every area that was analyzed. Through the use of a simulated mail session, the network resources for four electronic mail systems were evaluated. The relative financial resources necessary to procure and support each mail system were also compared as part of the topology evaluation. The last evaluation criteria was each mail system's user interoperability efficiency which is dependent on the

system's availability and reliability. The highest and lowest mail host topologies in each efficiency criteria are summarized below.

Network Resource Evaluation:

1. The INFOMAIL architecture was the most inefficient mail system architecture in its use of network resources because of its centralized architecture.
2. The local mail host architecture proved to be the most efficient in its use of network resources because of its highly distributed architecture and minimum dependence on the network.

Financial Resource Evaluation:

1. The local mail host mail system utilized financial resources more efficiently than the other systems due to its reliability in design and maintenance concept.
2. The distributed mail system required the greatest financial resources because of its multiple locations with its maintenance intensive equipment.

User Interoperability Evaluation:

1. The local mail host system had the highest user interoperability efficiency because of its highly distributed architecture.
2. The INFOMAIL system had the lowest interoperability efficiency due to its very centralized architecture.

These same criteria and evaluation techniques were also applied to the user's I/O device to determine the most efficient terminal configuration. The results of this analysis showed the following.

1. The teletype was the most inefficient configuration in its use of network resources because of its inability to store and perform

editing off line unlike both the intelligent terminal and personal computer.

2. The teletype also required the greatest amount of financial resources because of its mechanical hardware. Both the intelligent terminal and the personal had higher efficiencies in this area because of their solid state hardware.
3. The intelligent terminals/personal computer was the preferred configuration in the user interoperability criteria because of its minimum mail system access time and high reliability. The teletype was the least attractive configuration because of its limited capabilities.

The access techniques for the user to interface to the network were examined to determine their limitations. The results indicated that the normal transmission mode of character at a time and remote echo, for the TAC and the host supported network access, is a significantly inefficient use of the network resources. The overall magnitude of the above summarized inefficiencies in all areas is an indicator of other lesser problems that were not covered in the analysis due to scope and time limitations. The following section discusses recommended changes resulting from the analysis.

7.2. Recommendation Strategy

DCA requested that the recommendations be prioritized according to the magnitude of the inefficiency they will alleviate and also the amount of resources that will be required to implement them. Each recommendation stands alone without the requirement for a previous one to have been implemented. Obviously, since most of the thrust of this

effort was on improving network transmission efficiency, the various independent recommendations will alter their expected network benefits when implemented together. As an example, the implementation of a less interactive communications mode on the network would improve network transmission efficiency and eliminate a portion of the justification and expected network performance improvement for a more localized topology. Nonetheless, because of the other mail system network and user enhancements provided by the more localized mail systems there is still adequate justification for both the network transmission and mail system topology recommendations to be implemented together. The dual breakout of prioritizations provides the manager with options to be engaged depending on the severity of the problem or the availability of resources.

7.2.1.0. Magnitude of Inefficiency Prioritized Recommendations

The following is a prioritized listing of recommendations according to magnitude, highest to lowest, of the inefficiency that will be corrected.

7.2.1.1. Transmission Mode Recommendation

The most far reaching inefficiency covered in the analysis was clearly in the network to user's I/O device interface which determines the echoing and packet transmission characteristics. This problem applies to all interactive character per packet communications on the network. Recommend that the transmission mode and echoing plans outlined in paragraph 6.3.4. and 6.3.5. be developed for both the TAC and the host network access. Also that these plans be evaluated

according to the test objectives in paragraph 6.3.7. A successful evaluation of this proposed plan on the MINET should be followed with its implementation on the DDW.

7.2.1.2. Mail System Topology

Although no design errors were revealed in the current INFOMAIL mail system and it adequately meets the current requirements, there is still room for improvement in network transmission efficiency. With a more localized topology, the highly inefficient character per packet transmissions from the interactive user I/O devices, could be limited to smaller areas of the network. If future requirements indicate a significant increase in DCA provided electronic mail service, then the development should be initiated on one or more alternative mail systems outlined in paragraphs 5.5., 5.6., and 5.7. The specific mail system, to develop, will be dependent on the magnitude and characteristics of the additional requirements and the amount of resources available to implement the recommended topology. In keeping with the overall prioritization strategy of this section, and including the DCEC provided efficiency criteria weighting factor, the following is a breakout, from highest to lowest, of the recommended alternative mail systems as to the magnitude of their total improvements to the network and to the mail system availability/reliability.

1. Local Mail Host.
2. Layered.
3. Distributed.

7.2.1.3. Terminal Interface Recommendation

In the same area of improving network transmission efficiency is the need to more effectively utilize terminals on the network. Since the terminal is provided by the user, DCA must encourage the use of more capable alternatives to the teletype. Use of both the, network resource efficient, intelligent terminal and the personal computer over the network will be increasing and therefore the opportunity to engineer a more effective interface, which will utilize the processor intelligence of these systems, should be initiated. Recommend that the outlined alternatives in paragraph 6.6. be utilized to improve this area.

7.2.1.4. Host Supported Access Interface Recommendation

Network transmission efficiency could also be improved by modifying the TELNET protocol on host supported accesses to permit the local echoing and multiple character at a time interactive communications as discussed in the previous recommendation. The magnitude of this task will be in convincing users to perform this upgrade on their equipment. An alternative technique to modifying the host operating system could be the development of an external interface device, containing the required software. Because terminal access through a TAC is the predominant network access technique for electronic mail the improvements in transmission efficiency due to the implementation of this recommendation will not be significant. Recommend that research and development begin on upgrading the TELNET protocol to incorporate this more transmission efficient option.

7.2.2. Magnitude of Resources Prioritized Recommendations

The following reflects the recommendations prioritized, from the lowest to highest, in the amount of financial resources required to implement them.

7.2.2.1. Transmission Mode Recommendation

As previously explained this recommendation has the possibility of reducing all user I/O interactive network requirements. Several concepts have been formulated, with two outlined in paragraph 6.3.4. and 6.3.5., which can implement this recommendation with mostly an alteration in software. The problem could be segmented into modifications to the TAC software and the access supporting network host's operating system.

7.2.2.2. Terminal Interfacing Recommendation

An alternative terminal configuration to the teletype must be impressed upon the network users. The personal computer and intelligent terminal both have significant improvements over the teletype. A more efficient interface between the network and the intelligent terminal/personal computer would provide an improvement in network transmission efficiency and an incentive to utilize either system over a teletype. Recommend development of a more flexible network interface that would utilize these user devices as more of a host-like device than a terminal.

7.2.2.3. Host Supported Access Interface Recommendation

An improvement to the TELNET protocol to provide more transmission efficient communications from a host supported network access is needed.

Because of the effort required to alter the TELNET protocol and then encourage users to adopt the modification, this recommendation is considered one of the more difficult to implement. Recommend that this TELNET protocol modification be researched and developed to improve network transmission efficiency.

7.2.2.4. Mail System Topology

An alternative mail system topology is warranted if a significant increase in electronic mail users is foreseen. The breakout of the several alternative systems into an implementation resource prioritized list results in the following.

1. Distributed.
2. Local Mail Host.
3. Layered.

The distributed system is based on a more user localized implementation of the current INFOMAIL system with the lowest implementation resources required. The local mail host architecture will require significant implementation resources but will provide the most efficient mail system within the network resource and user interoperability criteria. The layered mail system also improved the utilization of the network and user interoperability resources but had the highest implementation costs of all the mail systems. Recommend that the local mail host system be developed to cost effectively reduce the impact of electronic mail on the DDN.

7.3. Future Requirements

The key resource to implementing these recommendations is time.

Most of them will require software/hardware development or standards to be established or modified. In either case, the failure to program sufficient lead time against the recommendations may result in an inefficient implementation with negative side effects. To determine adequate lead time, the increase in requirements must be thoroughly understood. A visit with the DDN Program Management Office was an adequate educator in this area. The reason why this report does not contain a projected DDN topology or include a brief summary of expected requirements, is the rate of growth of the network. The DoD directive to utilize the DDN for data communications evoked a significant reaction in the data processing communities. The robustness of the capacity of the network, coupled with the segmentation of the research and development portion of the network from the rest of the DDN, and modifications to the current network topology, have absorbed this initial onslaught of additional requirements. The current revolution of information systems within the DoD in addition to the acquisition of approximately 40,000 Z-100 microcomputers, which can utilize data communications, is an indicator of the future requirements in numbers and characteristics (2:44). The future user will be utilizing a personal computer or a local area network to interface into the DDN. The interface with this user must be more effective in its use of network transmission bandwidth. Commercially, the concept of electronic mail has made considerable strides in supporting geographically dispersed industries. It offers a very reliable high speed communications media. The applicability of electronic mail to communications operations is just barely being tapped by today's

traffic. With the worldwide voice communications requirements of the DoD already taxing the Automatic Voice Network (AUTOVON); the solution to provide electronic mail service, almost as widespread as AUTOVON, seems to be inevitable. The current electronic mail system topology has been shown to be inefficient in its use of network resources, particularly when dealing with the interactive terminal, and its expandability is limited. The development of an alternative mail system architecture which will capitalize on the DoD proliferation of information systems seems to be prudent use of the key resource leadtime. As in the many DoD communications programs, requirements expand without an organized approach to accepting the additional users at a minimum delay, the new users will attempt to satisfy their requirements utilizing alternative mail systems. The potpourri of competitive mail systems will not be optimized as efficiently as the alternative mail systems discussed in this study. They will also not provide the essential operational control, that any common mail system possesses, nor will they be the most cost effective solution for the DoD.

7.4. Recommended Further Areas of Study

This effort identified several areas of inefficient use of the DDN transmission bandwidth. The one area that was not addressed in the end to end efficiency analysis of the INFOMAIL mail system on the DDN was the access line between the terminal and the FAC. The current methodology of allowing the user to determine the transmission bandwidth of this line without a requirements justification does not appear to be cost effective. A study of the parameters necessary to determine this

bandwidth could specify a procedure which would translate user requirements into a more supportable decision. Recommend that this area be studied to determine the most cost effective solution. An embellishment of the contents of this thesis could be a specific mathematical model of the various mail system topologies which would connect the current INFOMAIL users and indicate the impacts on the network based on the mail system. Recommend that this effort be pursued to help justify a mail system topology alteration.

Appendix - Terminal Network Resource Evaluation

A. Introduction

This section contains the calculations that were used to evaluate the network resource requirements of the three terminal configurations. This was accomplished through the use of a mail session model which represents the typical user/mail host interaction of generating/editing/posting/reading/filing/discarding electronic mail. The Movement Information Network (MINET) mail session model was applied against the three different terminal configurations to determine the number and distribution of packets generated by each system. These calculations provide a comparison of the terminal's efficiency in the use of the DDN communications capabilities. With a constant overhead of 520 bits per packet and 1008 bits as a maximum packet size, the most efficient use of the packet would contain 488 bits or 61 ASCII characters. Conversely, the least efficient packet would carry one bit of information. The normal transmission mode for the TAC is character at a time, which results in 8 bits of information per 520 bits of overhead. This section characterizes the three terminal configurations by the number and size of various packets. The metric for this analysis is the MINET mail session model which was developed by BBN with inputs from the MINET community in Europe. The following paragraph addresses some particular details of the mail session model.

A.1. Mail Session Model

The MINET was designed as the first network with electronic mail as its primary function. It was unique from the DDN because it had to

utiliize narrowband communications media for inter IMP trunks. The narrowband communications lines could only provide 9.6 kbps transmission speeds in comparison to the 50 kbps of the DDN. This requirement necessitated the most efficient design of the network and its interfaces. The requirement model used in this design effort was determined through surveys with the future MINET community, coupled with the projected expansion of these requirements, by BBN design engineers, as user familiarity with the system increased. The model was further adapted by BBN engineers to represent the typical mail session model characteristic of DDN users (14:25). The final revision of this model was done to more accurately portray the government sytle of written communications correspondence that DCA personnel use. This latest model adaptation amounted to the distribution of several coordination copies of each message. The following is an outline of the model's typical mail session:

A.1.1. Mail Generation, Editing, and Posting

The representative user composes a message to five other individuals (each name and address requiring 25 characters) and sends information coordination copies to another five individuals. His text is apporximately 35 lines (1505 characters) long and he needs to edit at least four errors that require at least ten lines of his message to be displayed per error. He views the entire message once in its entirety before sending the mail.

A.1.2. Mail Reading, Discarding, and Filing

The representative user reads one message, which contains a 1600

character header and text, and then discards or files it.

A.2. Assumptions

The network resource comparison was accomplished under the following assumptions:

1. The TAC is in its normal character at a time transmission mode for the teletype.
2. The intelligent terminal and personal computer are configured as storage and local editing systems, as evaluated in Chapter 6. During mail host command interaction, the TAC is in character at a time, while file transfers, during the text generation and reading, are accomplished in the line at a time mode.
3. All character at a time echoing is done in the normal remote echo mode from the mail host and in the local echo mode for the line at a time transmissions.
4. The access line transmission speed between the terminal and the TAC is at 9600 bps.
5. There is an average load of other terminal traffic on the TAC.

A.3. Terminal Evaluation

The following is the action by action breakout, in numbers and approximate size of packets, due to the mail functions according to the mail session model. In character at a time and remote echo mode, each character from the terminal requires two packets. One packet contains the input character and the other packet contains the same character from the mail host back to the terminal to provide an echo. Characters transmitted by the mail host are grouped into larger packets and even

into multiple packet messages. There is no echo required for the mail host. As an example, a user at a teletype would input the command "CREATE<carriage return>" which consists of 7 ASCII characters including the carriage return which results in 7 input packets and 7 received echo packets for a total of 14 packets. The INFOMAIL prompt from the mail host consists of "<linefeed>-->" which contains 5 ASCII characters with the linefeed all within one packet which does not require an echo packet. Line at a time with local echo mode allows a packet to contain a line of text, which for the MINET mail session model consists of 43 characters per line and packet. The TAC provides echoes to the terminal negating the requirement for the mail host to transmit them. In addition, the TCP acknowledgements between the TAC and the mail host, that indicates the transmitted message was received, are required which doubles the total number of packets transmitted. The number of actions that are required to complete each sequence of the mail function, in addition to their source as either user (U) or mail host (H), is provided in the evaluation. An example would be the user inputting 5 names and addresses which requires 5 separate actions (14:101-104). Under these guidelines the number of packets and their approximate size were calculated in the following tables for the various mail functions and terminal configurations.

A.3.1. Teletype Terminal Evaluation

Table A.0. Mail Generation, Editing, and Posting Packet Characteristics
from the MINET model for the Teletype Terminal.

Seq. No.	Description of Action	Origin	No. of Act.	No. of Char/Act.	No. of Pkts/Act.
1.	INFOMAIL Prompt	H	1	5	1
2.	Request to CREATE	U	1	7	14
3.	Prompt for Each Addressee	H	5	5	1
4.	Enter Recipients Names & Address	U	5	16	32
5.	Sender's Name and Address	H	1	16	1
6.	Prompt for Subject Title	H	1	11	1
7.	Enter Subject Title	U	1	30	60
8.	Message Date	H	1	30	1
9.	Prompt for Coord. Copies	H	1	6	1
10.	Enter Each Coord. Copy Name & Address	U	5	16	32
11.	Prompt for Text	H	1	8	1
12.	Insert Text of Message	U	1	1505	3010
13.	INFOMAIL Reports on Message Status	H	1	45	1
14.	INFOMAIL Prompt	H	1	5	1
15.	Request Editor	U	1	5	10

Seq. No.	Description of Action	Origin	No. of Act.	No. of Char/Act.	No. of Pkts/Act.
16.	Prompt for Editor	H	2	10	1
17.	Request to Display Ten lines of message	U	4	5	10
18.	Ten lines of Message Displayed	H H	4 4	427 3	7 1
19.	Cursor Command to Line Five to Edit	U	4	5	10
20.	Edit Message	U	4	10	20
21.	Display Edited Line	H	4	43	1
22.	Request to Display Entire Message	U	1	5	10
23.	Display Message	H H	1 1	1586 14	26 1
24.	Exit Editor	U	1	5	1
25.	Response on Message from INFOMAIL	H	1	45	1
26.	INFOMAIL Prompt	H	1	5	1
27.	Move Message to OUTBOX	U	1	20	40
28.	INFOMAIL Message Status	H	1	30	1
29.	INFOMAIL Prompt	H	1	5	1
30.	Command Immediate Mailing of OUTBOX Contents	U	1	5	10
31.	INFOMAIL Message Status	H	1	23	1
32.	INFOMAIL Prompt	H	1	5	1

Mail Generation, Editing, and Posting Results:

Total Data Packets Originated by Terminal	3644
TCP Packet Acknowledgements	3644
Total Data Packets Originated by the MAIL Host	89
TCP Packet Acknowledgements	89
Total Data Packets with Acknowledgements due to this Session	7466

Table A.1. User/Mail Host Mail Generation, Editing, and Posting Packet
Length Frequency Distribution from the MINET model for the Teletype
Terminal

Packet Length	Frequency Distribution
<u>(Char/Pkt)</u>	<u>%</u>
1-20	98.3
21-40	0.08
41-61	1.6

NOTES:

1. Characters are 8 bits long.
2. These values do not include TCP acknowledgements.

A.3.1.1. Mail Reading, Discarding, and Filing

Terminal configuration is independent of the transmission efficiency in performing these functions with the current DDN configuration.

Table A.2. Mail Reading, Discarding/Filing Packet Characteristics from the MINET model for the Teletype, Intelligent Terminal, and Personal Computer

Seq. No.	Description of Action	Origin	No. of Act.	No. of Char/Act.	No. of Pkts/Act.
1.	INFOMAIL Prompt	H	1	5	1
2.	Read Message in INBOX	U	1	15	30
3.	Display Entire Message	H H	1 1	1586 14	26 1
4.	INFOMAIL Prompt	H	1	5	1
5.	Discard or File Message	U	1	8	16
6.	INFOMAIL Status on Message	H	1	23	1
7.	INFOMAIL Prompt	H	1	5	1

Mail Reading, Discarding/Filing Session Results:

Total Data Packets Originated by Terminal	46
TCP Packet Acknowledgements	46
Total Data Packets Originated by Host	31
TCP Packet Acknowledgements	31
Total Data Packets with Acknowledgements due to this session	154

Table A.3. User/Mail Host Mail Reading, Discarding/Filing Session Packet Length Frequency Distribution from the MINET model for the Teletype, Intelligent Terminal, and Personal Computer

Packet Length <u>(char/pkt)</u>	Frequency Distribution <u>%</u>
1-20	64.93
21-40	1.3
41-61	33.77

NOTES:

1. These values do not include TCP acknowledgements.
2. Characters are 8 bits long.

A.3.2. Intelligent Terminal and Personal Computer Evaluation

Table A.4 Mail Generation, Editing, and Posting Packet Characteristics
from the MINET model for the Intelligent Terminal and the Personal
Computer

Seq. No.	Description of Action	Origin	No. of Act.	No. of Char/Act.	No. of Pkts/Act.
1.	INFOMAIL Prompt	H	1	5	1
2.	Request to CREATE	U	1	7	14
3.	Prompt for Each Addressee	H	5	5	1
4.	Enter Recipient's Name & Address	U	5	16	32
5.	Sender's Name & Address	H	1	16	1
6.	Prompt for Subject Title	H	1	11	1
7.	Enter Subject Title	U	1	30	60
8.	Message Date	H	1	30	1
9.	Prompt for Coord. Copies	H	1	6	1
10.	Enter Each Coord. Copy's Name & Address	U	5	16	32
11.	Prompt for Text	H	1	8	1
12.	User Control Sequence to TAC to Change to Line at a Time Mode/Local Echo				

Seq. No.	Description of Action	Origin	No. of Act.	No. of Char/Act.	No. of Pkts/Act.
13.	Transfer Text from Terminal Storage to Mail Host	U	1	1505	43
14.	User Control Sequence to TAC to Change to Character at a Time Mode/Remote Echo				
15.	INFOMAIL Reports on Message Status	H	1	45	1
16.	Command Immediate Mailing of OUTBOX Contents	U	1	5	10
17.	INFOMAIL Message Status	H	1	23	1
18.	INFOMAIL Prompt	H	1	5	1

NOTE: All Editing is done locally and does not require network or mail host access.

Mail Generation, Editing, and Posting Results:

Total Data Packets Originated by Terminal	311
TCP Acknowledgements	311
Total Data Packets Originated by Host	19
TCP Acknowledgements	19
Total Data Packets with Acknowledgements due to this Session	660

Table A.5. User/Mail Host Mail Generation, Editing, and Posting Packet Length Frequency Distribution from the MINET model for the Intelligent Terminal and the Personal Computer

<u>Packet Length</u> <u>(Char/Pkt)</u>	<u>Frequency Distribution</u> <u>%</u>
1-20	88.79
21-40	0.606
41-61	10.6

NOTES:

1. These values do not include TCP acknowledgments.
2. Characters are 8 bits long.

Table A.6. Average Packet Utilization Rate Comparison between Terminals based on the MINET Model

<u>Terminal</u>	<u>MAIL FUNCTION</u>	
	<u>Generate/Edit/Post</u>	<u>Read/Discard/File</u>
Teletype	3.45%	35.85%
Intelligent		
Terminal and	9.66%	35.85%
Personal Computer		

A.4. Terminal Packet Characteristics Analysis

The results show the obvious advantage of the intelligent terminal and personal computer in use of the network bandwidth. Specifically, the text generation and editing functions, in the TAC's normal character at a time and remote echo mode, created the largest percentage of inefficient small packet traffic for the teletype but were the areas in which the two alternatives had their greatest advantages. The data also shows the reduction in packet traffic when the TAC transmission mode is altered from its normal character at a time and remote echo as seen in Table A.0 (Sequence No.12) to the line at a time and local echo as seen in Table A.4 (Sequence No. 13). The TAC could have been configured in the line at a time and local echo mode for the teletype evaluation but single command characters, required for editing, would not have functioned properly in this mode. The two alternative configurations did not have a need for mail host editing since this function was accomplished locally. The final conclusion from these results is the utilization of each packet's transmission capability as determined by the amount of characters in each packet or in packet length. Tables A.1, A.3, and A.5 reflect the frequency distribution of three ranges of packet sizes. The lowest range from 1 to 20 characters per packet represents the most inefficient use of the network transmission bandwidth and results from the TAC's character at a time and remote echo mode with the interactive traffic generated from the MINET model. The 21-40 characters per packet range indicates a higher transmission efficiency and was generated through the query/response actions in the model. The 41-61 range is the most efficient use of the packet and the

packet and the network transmission bandwidth and was primarily due to file transmissions. The average utilization rate of each packet, which provides a more accurate reflection of network transmission, is compared between the various configurations in Table A.6. Once again it is apparent that the I/O device that communicates through large packets, more efficiently utilizes the network resources. This difference demonstrates the enhancement of a teletype terminal modified with a local storage and editing capability. Further improvements could be realized in the intelligent terminal and personal computer options by storing the format of the entire message, including the header, which could permit the entire mail message to be generated and edited locally with the final product transmitted to the INFOMAIL mail host.

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This investigation evaluated the efficiency of the electronic mail system INFOMAIL as applied on the Defense Data Network (DDN). The evaluation compared the financial, network, and operational requirements of the INFOMAIL system and three alternative mail system topologies to determine recommended modifications to the current system.

The results indicated the current mail system topology is inefficient in its use of network transmission bandwidth and in providing high system availability and reliability. The alternative mail system topologies exceeded the current system in these categories.

This study also addressed the user's interface to the INFOMAIL mail host through the I/O device and the DDN. The evaluation of these components in their utilization of network transmission bandwidth indicated the inadequacies of the network access components and terminals. Recommended modifications to improve these inadequacies were also included.

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